LIVING IN A WORLD OF SCIENCE

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MAGNETISM AND ELECTRICITY

MORRIS MEISTER

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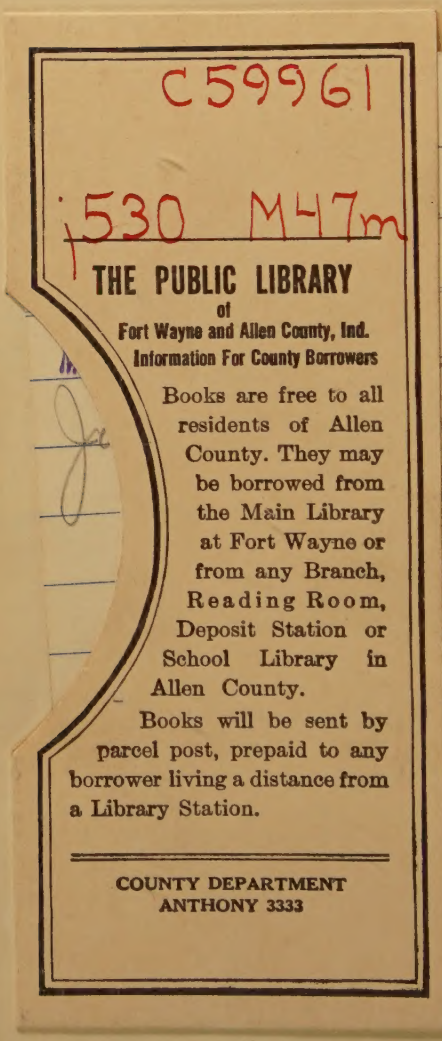
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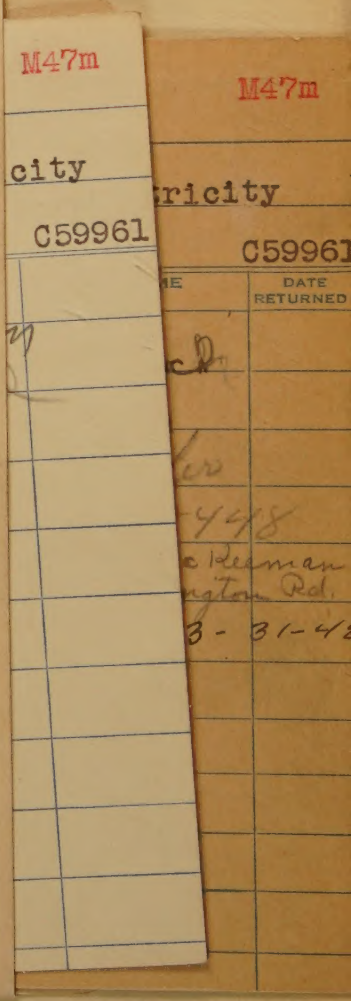

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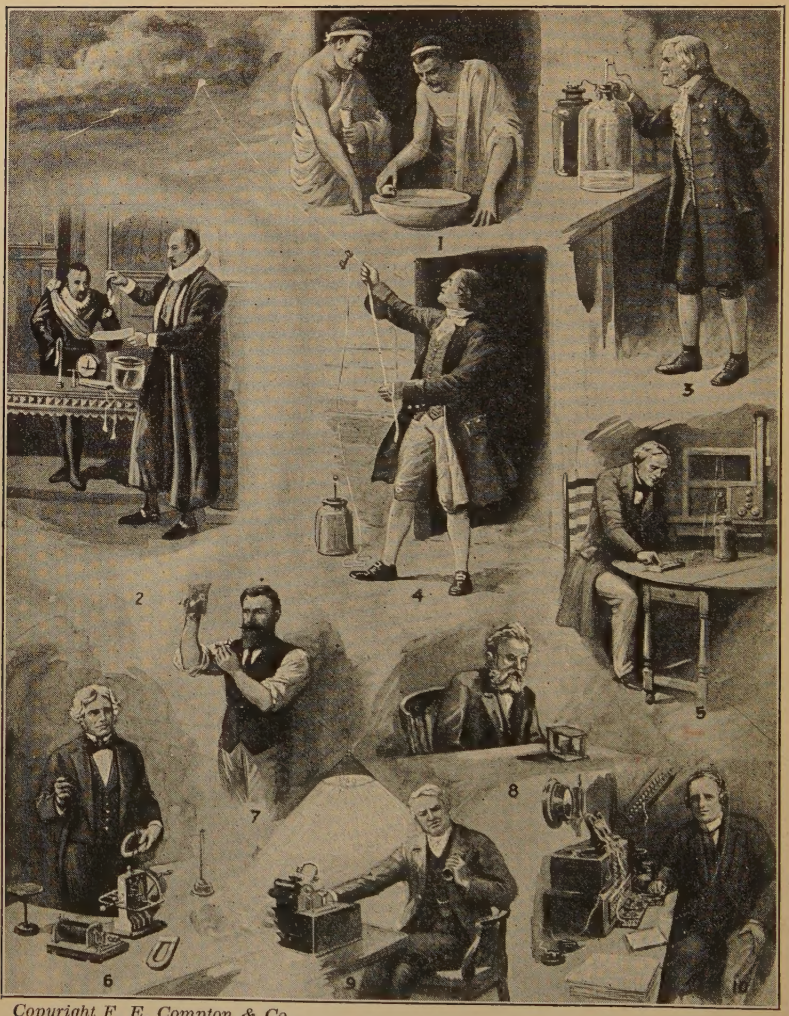

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1. THRILLING MOMENTS IN THE HISTORY OF ELECTRICAL SCIENCE

1. Romans experimenting with a lodestone.
2. Dr. Gilbert experimenting with a magnet.
3. Cavendish experimenting with electricity.
4. Franklin proving that lightning is electricity.
5. Morse listening to the first telegraph.
6. Faraday demonstrating the principle of induction.
7. Roentgen examininng the first X-Ray picture.
8. Bell talking over the telephone.
9. Edison listening to the phonograph under the electric light.
10. Marconi listening to a wireless message.

From Compton's Encyclopædia.

LIVING IN A WORLD OF SCIENCE

MAGNETISM AND ELECTRICITY

BY

MORRIS MEISTER

NEW YORK TRAINING SCHOOL FOR TEACHERS
COLLEGE OF THE CITY OF NEW YORK
AND
EDITOR, "THE SCIENCE CLASSROOM"

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TO THE TEACHER

We live in a world of science. Never before in the history of mankind have scientific knowledge, invention, and method affected so greatly every event and every act of daily life. Each day brings some new discovery, often so far-reaching in its human applications, that the science teacher is continually faced with the problem of interpreting the constant flow of scientific achievement.

Obviously, any significant understanding of our complex scientific environment must be based upon the fundamental concepts of science. These concepts become the sign-posts which direct the pupil through the maze of science experience and give meaning to the natural phenomena of the world in which he lives.

Any organized study of our environment which will explore pupil interests and possibilities of future science study can be effected most readily through application of the laws of learning. These laws, insofar as they are known and established, must operate also in the formation of good thinking habits and in an appreciation of the method of science, which is perhaps the outstanding contribution of science to the age in which we live.

"Living in a World of Science" is based upon the above-mentioned objectives of science teaching. It embodies the essence of many years of science classroom experience and of many contacts with the problems of science teachers in various parts of the country.

In its selection of content, the series is guided by three major principles:

I. There is general and wide acceptance of certain major units of study for the course in science.

II. Local conditions must be permitted to determine the degree of emphasis upon units and the order in which they are to be considered.

III. The further selection of material and activities for each unit must be based upon a set of criteria which are educationally valid.

Thus, in meeting the first of the principles above, the series includes such units as: Water, Air, Heat, Health, Electricity, Energy, Communication, Transportation, etc. Within its organization are also included the basic concepts of astronomy, earth science, the weather, and of plant and animal life.

The second guiding principle has resulted in a division of the book into four parts, called books. This makes for flexibility. Also, it minimizes the formidable aspect of so many of our science textbooks, which seem to be far too large for one volume and too small for adequate treatment of all that is included.

In complying with the third of the principles set forth above, the following criteria were applied by a committee of science teachers, in determining the most desirable science subject matter:

1. To what extent can the item of content be taught objectively? (Weight 4.)

2. To what extent does the item interest the pupil? (Weight 3.)
3. To what extent is the item adapted to the abilities of the pupil? (Weight 2.)
4. How frequently does the item occur in the normal experience of the pupil? (Weight 2.)
5. To what extent does the item represent a knowledge or skill which the pupil will find of value when an adult? (Weight 2.)

From this somewhat objective method of selection, a body of highly educational content emerged. The sixty items of greatest worth, as indicated by their final numerical ranking, became the basis for the material presented in this series.

The unifying thought around which "Living in a World of Science" has been organized is that the pupil begins with a study of the science which contributes to *basic life needs*, after which he considers the *improvement of life through the utilization of science.* Thus, Book I deals essentially with Water and Air as basic life needs and Book II with Heat and Health as basic life needs. Book III in its development of Magnetism and Electricity and Book IV in in its treatment of Energy and Power stress the part that science is playing in making life more comfortable, more convenient, and more interesting.

Within each book, the organization centres around sixteen or seventeen units or major concepts. On the assumption that the school semester rarely offers more than seventeen "working weeks," a chapter a week becomes a feasible rate of achievement for pupil and for teacher. Thus, the four books provide adequately for a two-year course in science.

The development of each unit in each of the four books may be readily understood from a brief perusal of the Table of Contents. We begin with an Approach, designed to explore and arouse interest, after which the "steps" or contributing concepts are set forth in simple and complete sentence form. Each of the "steps" presents a discussion which takes its origin from an experiment or a series of experiments that can be performed by pupil or teacher at the demonstration table. The apparatus in every case is such as can be made with inexpensive and readily available materials. When the major concept has been established through demonstration, discussion and pupil activity, a number of outgrowths are suggested. Different pupils will be stimulated by different problems. These outgrowths are of great importance in the learning process. Indeed, effective learning is dependent upon them. Further explanation of this feature of the book is given below.

SPECIAL FEATURES

1. *The Approach to the Unit*

The author is in sympathy with the practice of unit introduction by "pretest," "survey questions," "over-view," etc. However, experience indicates that the same ends are sometimes better served by the use of biography, science "fiction," and adventure. Each unit or chapter has, therefore, been introduced with a science "story." The aim in this type of approach is to provide the pupil with several pages of interesting reading. The effect is to raise a problem and to motivate the development which follows.

2. *The Page of Problem Pictures*

Each unit or chapter closes with a page of problem pictures. If the important ideas have been mastered, this page stimulates further pupil activity. The pictures may raise a question to be answered, a subject to be investigated, an experiment to be performed, or a puzzle to be solved. Pupils are assigned to these problems so that they may report the solutions to the class.

3. *How Much Do I Remember?—A Review Test*

Here the material of each unit is reviewed in one or another form of "short-answer" type of test. The author has not limited himself to one style of test. In fact, he has deliberately made use of variety in order to suggest possibilities to the teacher in the matter of test construction. The uses to which this feature of the book may be put include periods of directed study and achievement-testing of minimum essentials.

4. *Things to Read About and Think About*

Toward the close of each unit the pupil finds several paragraphs of brief description, which open new fields for thought and investigation. If he is interested, he may find supplementary reading material in the books referred to and on the pages mentioned. Three well-known and popular reference books have been used for these supplementary readings. It is suggested that opportunity be given pupils to report on their readings and investigations.

5. *Things to Do and Make*

This section closes each unit or chapter. It is especially designed for activities involving construction and experimentation. Pupils and teachers will find here a fruitful source of new démonstrations, home experiments, and science club activities. The specific page references for each project are to nine or ten books which may be made available in the class or school library.

It is important to note that the four features last mentioned need not be applied to all pupils; nor need all of the activities be included for any one pupil. They are intended as stimuli for the varied interests and abilities which are to be found among pupils under normal teaching conditions.

M. M.

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Acknowledgment is also made of the kindness and courtesy extended the author in the matter of use of illustrations belonging to the following organizations:

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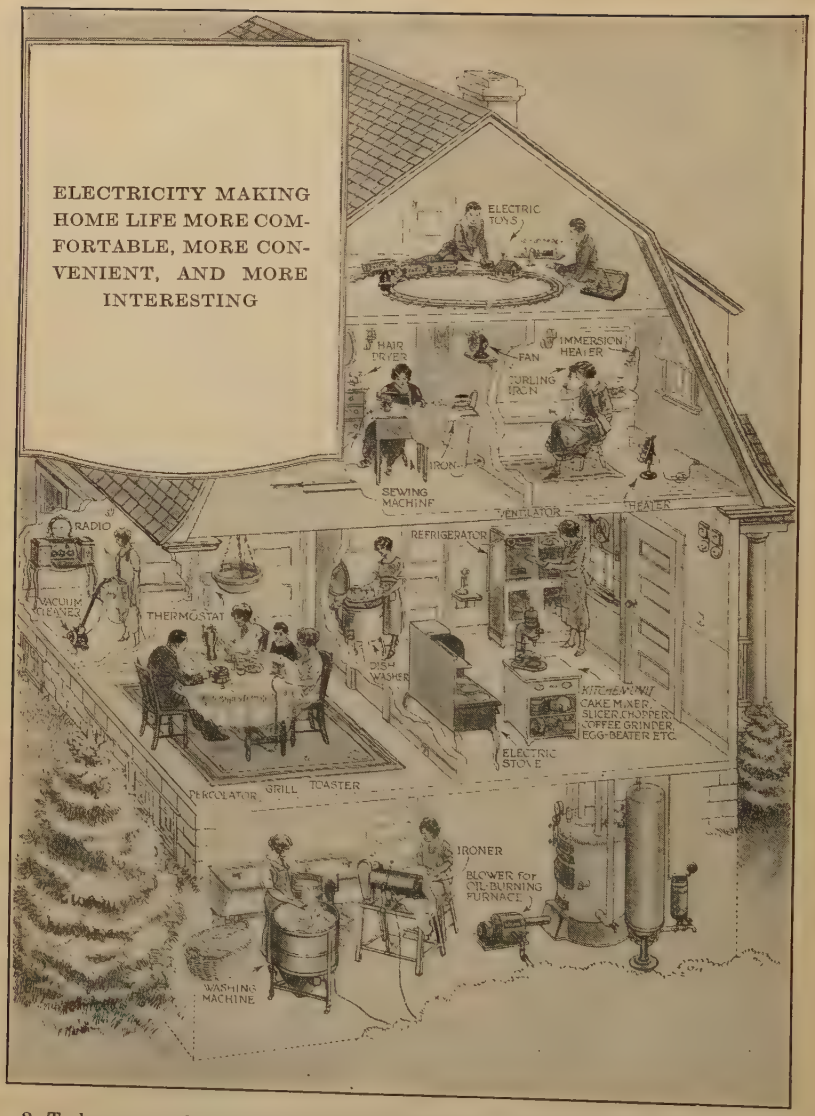
TO THE PUPIL

When Robinson Crusoe found himself shipwrecked on an island —alone, and with no possible way of getting back to a civilized country—he realized that if he was to live he must depend entirely on himself. And so his first efforts were directed toward finding food and water. Having found these, his next thought was for a warm and safe place to sleep, after which he gave his attention to the question of clothing. Only after his basic life needs were supplied did he begin to think of improving his surroundings. But he spent very much more time in devising comforts and conveniences than he did in finding bare necessities.

We are all of us like Robinson Crusoe. Whether we live alone or whether we live in large cities, we are not satisfied for very long with merely the necessities of life. We must have comforts and conveniences. In fact conveniences soon become necessities. That is what has happened in our modern world, chiefly through the advance of science and its applications to everyday life.

In this book we shall study the way in which the laws of science have been used by man to make living more comfortable, more convenient, more economical, and more interesting. Thus far our study of science has dealt with some of life's basic needs. We have studied the air and its relation to life. We have considered the question of water, its importance and its uses. We have been learning about heat and the way in which it affects our bodies and our homes. To the age-old forces of air, of water, and of heat, science has added for us the fascinating knowledge of a new force —the force of electricity. This force is as old as the universe, but a knowledge of it has been gained only in the last one hundred years. In fact, it is only in the last twenty years that electricity has entered and changed our home, our schools, our streets, our business, our industries, our recreations, our cities, our country, and the whole civilized world.



2. To how many different uses has electricity been put in the modern home shown above? Make a list of these uses. Are there any uses of electricity in the home which the picture does not show?

CHAPTER I

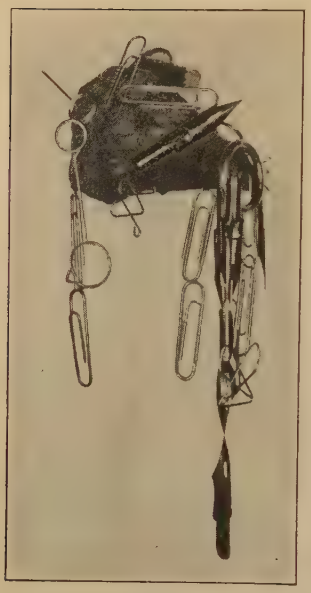
MAGNETS AND MAGNETISM

How did it all start? Who discovered the first magnet? Who is responsible for the idea which set men thinking and experimenting until, from puzzling over the peculiar behavior of a piece of stone, they have developed the radio set and television?

Unfortunately we do not know the complete answers to these questions. There are many legends, many stories, and many guesses. According to one account there was a man named Magnes, a shepherd who lived in Asia Minor, who one day discovered to his surprise that the iron end of his shepherd's stick stuck fast to a dark-colored rock against which he had rested it. Whether the name "magnet" came from the name of this shepherd, or whether it was derived from the name of a province in Asia Minor (Magnesia), is a matter of dispute. Some believe that the word "magnet" is derived from the Latin word *magnus*, which means great or heavy; since iron ore is so heavy. There are many stories, too, of certain Chinese emperors who used magnets as compasses more than forty-five hundred years ago. In the writings of ancient peoples, such as the Hebrews, Greeks, and Romans, the magnet is referred to as a "lodestone," which means "leading-stone" or "directing-stone."

We can be certain that for many hundreds of years men knew about a certain kind of iron ore called the *lodestone* and about its mysterious powers:

(a) It can attract pieces of iron.
(b) When freely suspended, it will always swing around so as to point north and south.
(c) By rubbing pieces of steel with it, the steel also becomes possessed of the powers of lodestone.



3. What one lodestone was able to hold.

Because iron ore did something which other materials could not do people became superstitious about it. They called it the magic stone. Instead of observing it carefully and experimenting with its force, men soon began to tell fanciful tales about it. They told of ships which fell to pieces because an iron ore mountain pulled out the nails which held the boards together. For a long time men were content to believe these tales, for the idea of *trying things out*—of testing the behavior of materials and forces—is one which is really new in the history of mankind. It was only in the year 1600, after man had known about the lodestone for three thousand years, that William Gilbert made the first important experiments in magnetism. It has taken three hundred years more of experimentation to enable us to use the magnet in a telegraph, in a telephone, in a dynamo, and in a radio.

In figure 4 you see a powerful magnet—a magnet that reminds you of the one which in

4. The "skull-cracker" at work.

the ancient story drew the nails out of a ship. The picture is of a real magnet. In the factory where we saw it, it is called a "skull-cracker." It lifts a ball of iron 12,000 pounds in weight, then drops it on metal castings so as to break them into small pieces. These pieces are then ready for the furnace, where they are melted for further use.

Did you ever play with the toy shown in figure 5? You could make one yourself easily enough. Perhaps you have other interesting magnetic toys. Bring them to school and show them to your teacher and to your classmates.

Not long ago, a boy was rushed to the hospital with a fragment of iron in his eye. The doctor used a magnet to attract it out from the eye.

And what do you think of this? Would a knowledge of magnetism have helped Mr. Brucker?

"MAGNETIZED" DOLLARS FAILED TO FIND BURIED INDIAN WEALTH

Special to The New York Times.

KANSAS CITY, Mo., Jan. 5—J. B. Toland is under bond to appear before the Federal court in Topeka, Kan., to explain how he planned to "magnetize" $4,000 turned over to him by W. C. Brucker, a Jamestown, Kan., farmer so that it would discover $475,000 in Indian treasure said to be buried on Brucker's farm.

Brucker charges that Toland told him there was a large sum of money on his farm awaiting discovery by magnetized dollars. Brucker mortgaged the farm for $4,000 and turned the money over to Toland. When nothing happened, Brucker told the authorities he believed there was a catch somewhere in the proposition.

THE BEST WAY TO LEARN ABOUT MAGNETS

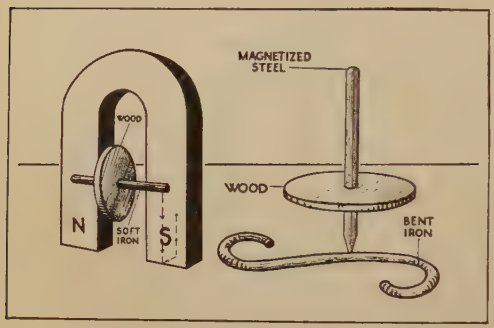
The best way to understand how magnets behave is to play with them and to experiment with them. To do this every boy and girl should collect a few necessary materials. These are easy to get and will be a beginning for *your own scientific laboratory.*

Materials you should have: A few old razor blades. A steel spring from an old alarm clock. Nails of all sizes. A steel file.

Pins. A pair of pliers. A strong pair of scissors. Some corks. Needles. Some cotton and silk thread. A horseshoe magnet. A knife. A hammer. A spool of copper wire. One or two dry cells (batteries).

1. Magnets are bodies that attract iron and steel

Magnets attract iron. Try this experiment. Into any kind of box (a chalk box) put a lot of nails, match sticks, keys, pins, clips, pen-points, pieces of paper, string, pieces of copper wire, glass chips, a few pennies, and other materials. Shake them up. Now insert your horseshoe magnet, stir it around a bit and lift it out. What will come out? No matter how often you try this, only the iron or steel objects will be drawn out. With a magnet you will never lift out a penny or a piece of glass or a match stick. If you succeed in lifting out materials other than iron or steel you must have used something other than a magnet. In fact, you can be certain that wherever you find magnetic attraction you will find that it is iron which is being attracted.



5. Two interesting magnetic toys, easily made.

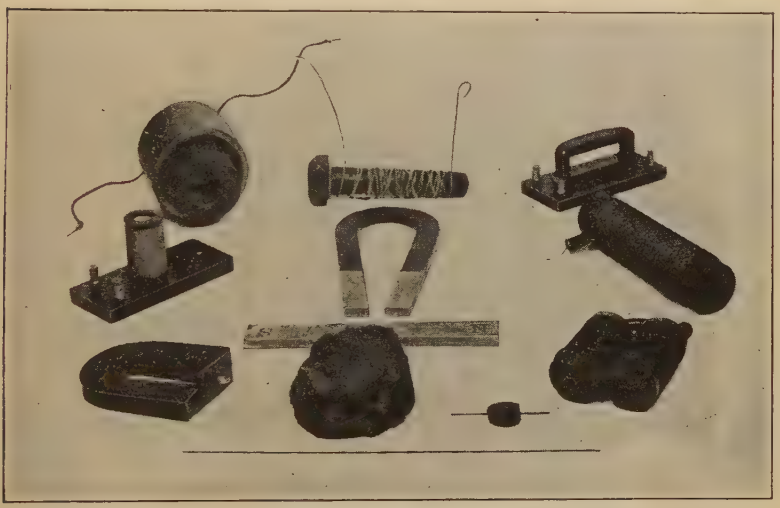
In a scientific laboratory we once saw a magnet attracting nickel and a few other substances. We even saw a magnet repel certain substances. But these attractions and repulsions are so slight that we can safely say that magnets really attract only iron.

2. There are several kinds of magnets

In the introduction on page 1 we told you about a kind of iron ore which attracts iron. Such a magnet is called a *natural magnet* because it is found in nature. It is also called *lodestone* for the reason which we have already explained on page 1. Your

teacher will show you some lodestone and you can find out for yourself that it will attract iron.

If you have a horseshoe magnet in your collection of materials you probably know that such a magnet is not found in nature. It must be manufactured. Such magnets are called *artificial magnets*, because they are made by man. Sometimes, they are not bent into the shape of a horseshoe, but remain a straight bar. Then, we call them *bar-magnets.*



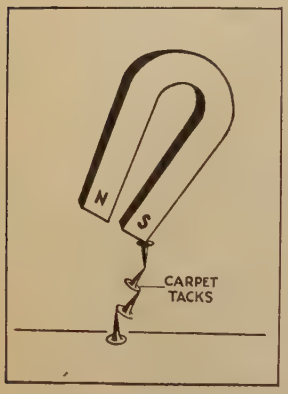
6. How many natural magnets can you find in this picture? How many bar-magnets? Permanent magnets? Electromagnets? Horseshoe magnets? Artificial magnets?

Horseshoe magnets and bar-magnets will never fail to attract iron. They may get weaker after you have had them for some time, but they hold their magnetism for a very long time—even forever, if you learn how to store them away when not in use. But there are some magnets which will attract iron for a short time only.

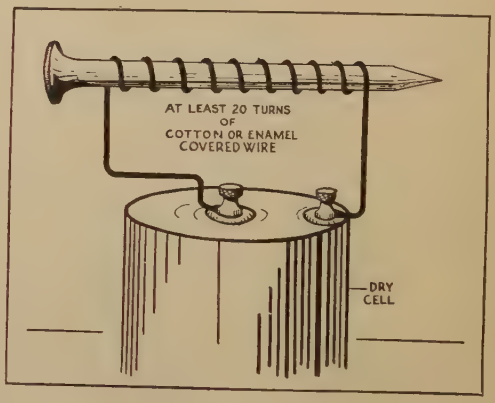
Try this experiment: Let your horseshoe magnet hold an iron nail. To the end of this nail bring another nail. The second nail will be attracted to the first nail. See how long a string of nails you can attach in this way. See figure 7. Now remove your horseshoe magnet. What happens to your string of nails? The

nails are magnets only while the horseshoe magnet is holding the first nail. As soon as it is removed the nails lose their magnetism. The horseshoe magnet may then be called a *permanent magnet*, while the nails may be called *temporary magnets*.

If you want to try another interesting experiment, hang a needle from your horseshoe magnet and attach another needle to the end of the first. See how long a string of needles you can hold in this way. As you did before, remove the horseshoe magnet.



7. Permanent horseshoe magnet.



8. Electromagnet.

Aren't you surprised to see that several of the needles still hang together? This is different from the way in which the nails behaved. You see, the nails are made of soft iron and the needles of hard iron or steel. Nails can be only temporary magnets, but steel needles can become permanent magnets.

The most interesting kind of magnet is another kind of temporary magnet which is called an *electromagnet*. This is the way you can make one. Take an iron nail and wind a piece of your cotton-covered copper wire around it. Attach the ends of the wire to your cell (battery). See how many nails your new magnet can now attract. But be careful that your connections with the cell stay in place. See figure 8. Just as soon as you disconnect, the magnetism of your nail is lost. We shall learn more about electromagnets in the next chapter.

3. How to make magnets

In the experiments which you have already performed you have learned to make magnets in different ways. Just bringing a piece of iron or steel near or against a magnet makes the iron or steel into a magnet. It seems that the horseshoe magnet *induces* the iron or steel to become a magnet. This is called magnetizing by *induction*. You can make hundreds of magnets by rubbing a piece of steel on the end of a magnet. See if you can make your knife-blade a magnet by rubbing it on the end of a horseshoe magnet. Magnetize a file and a pair of scissors in the same way. The strange thing about making magnets in this way is that no matter how many magnets you make, the original magnet does not lose any of its magnetism. One might think that the first magnet would become weaker from the continual rubbing. It does not, however. Perhaps you can think of a good reason for this. Speak to your teacher about it and find out what she says.

9. How to make a useful electromagnet.

The very best way to make strong magnets is the way in which they are made in factories. If you are a real scientist you will want to make magnets in this way; and it really is not hard to do.

Get a piece of mailing tube, the kind used in sending magazines or papers through the mails. Almost any cardboard cylinder will do. You can even make one by bending a piece of cardboard into a cylindrical shape. Around this cylinder wind as much copper wire as you can get. 300 feet of wire will make an excellent coil. Twist the bare ends of the wire around two paper clips and fasten the clips to opposite ends of the cylinder. See figure 9. Now bring the wires from a battery to the paper clips. To make a magnet, all you need do is to place a piece of

steel inside the cardboard cylinder. In the picture shown in figure 9 you see inside the cylinder two files, a pair of scissors, one knife, and five knitting needles. If the battery and the coil are connected for but one second, all of the objects inside the cylinder are made into strong magnets.

If you make this coil, be sure to bring it to class and show it to your teacher. Your classmates will all want to turn their knives into magnets by placing them inside your coil.

4. How to destroy a magnet

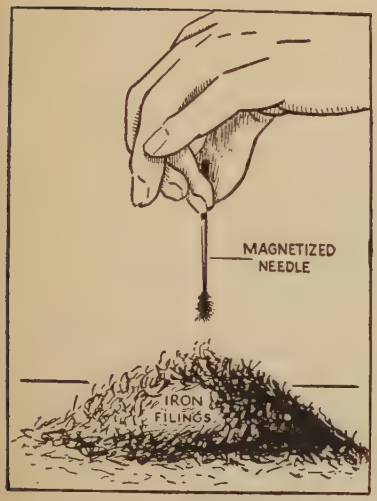
Take a needle which you have magnetized and, holding it with a pair of pliers, heat it in the flame of a gas stove until it is red hot. If you get it hot enough it will lose all its magnetism. Can you think of a good reason for this?

5. The magnetic attraction is greatest at the poles

By this time you may have noticed that not all parts of a magnet attract iron with the same strength. Try this experiment: First make some iron filings by filing down some iron nails. When you have a little heap of such filings bury a magnetized needle in the heap. Remove the needle and shake it gently. Most of the filings drop off, except at the ends, where they cling in great numbers. At the centre of the needle practically no filings stick. See figure 10. Try your other magnets in the same way. Always, the ends show the greatest attractive force. The points where there is greatest attraction are called the *poles*. In a bar-magnet the poles are near the ends. That is why a bar-magnet is bent into a horseshoe. This brings the ends together, so that you can get the greatest possible pull at one end.

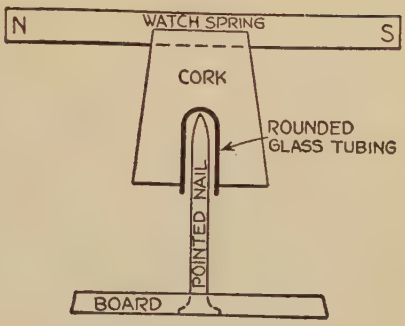
6. When a magnet is freely suspended, the same pole always points north

Take one of your magnetic needles and stick it through a flat cork. See figure 11. Float the cork in a dish of water. See figure 13. Watch it turn. Let it come to rest. Do you note the direction in which it points? Make it point in another direction.

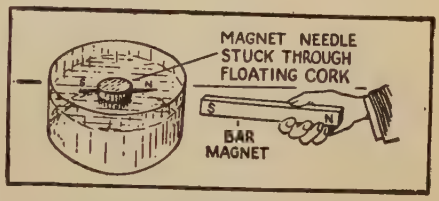


10. Attraction greatest at the poles.

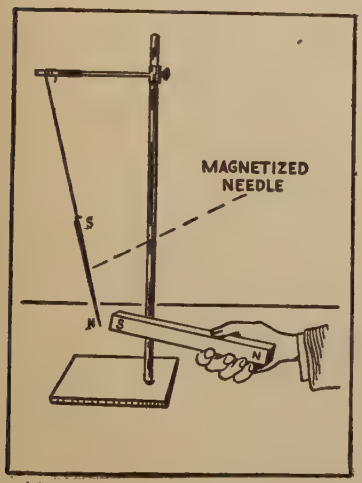
11. How to stick the magnetized needle through the cork.



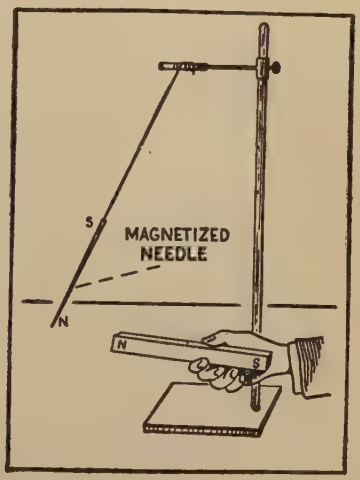
12. An easily-made magnetic compass.



13. Floating magnetic needle.



(*a*)



(*b*)

14. (*a*) Unlike poles attract each other.
(*b*) Like poles repel each other.

Can you do this? It comes right back to the same direction every time. One end always seeks the north and, of course, the other end seeks the south.

Such a needle would be a useful thing to have with you on a hike. If you ever lost your way you could use it to tell you where "north" was. It would act as a *compass*. As a matter of fact that is what a compass is. Of course, it is much more convenient to pivot the needle in a little glass-covered case than to float it on water. Make a homemade compass as shown in figure 12.

7. Unlike poles attract each other, like poles repel

Here is one of the most fascinating things about magnets. You can have a great deal of fun experimenting with compass needles, by preparing two magnetic needles, each stuck through a flat cork. Float each in a different glass of water. Keep the glasses about two feet apart and let each needle come to rest, with each pointing north and south. Try to remember the ends which point north. Now bring the glasses near each other so that the north-seeking ends come as close as possible to one another. Do you note what happens? The north-seeking ends repel each other, because the corks float away from each other. So do the south-seeking ends. After a while the corks turn around so that the south-seeking end of one needle is near the north-seeking end of the other needle. Put both needles in one dish and see how they behave. Like-seeing poles always repel each other; unlike-seeking poles attract each other. See figures 14*a* and 14*b*. If that is true you can find out which end of your magnetized knife is north-seeking and which end is south-seeking. Just bring one end of your knife to the north-seeking end of the floating needle. If there is attraction, that end of the knife must be a south-seeking pole. Now you have a way of labeling all your magnets. Do this by marking all the north poles with chalk.

8. The earth is a magnet

Why do all your floating magnetic needles point north and south? For many years scientists wondered about this. Many

explanations were offered. Perhaps *you* can offer an explanation. The real answer came only three hundred years ago, after man had known of this peculiar behavior of magnets for thousands of years.

The answer accepted by science to-day is that the earth is a magnet. If the earth is a magnet, then the earth, like all magnets, must have poles. The poles of the earth-magnet would then attract and repel the poles of any magnet on the earth. Thus, we can see that the north-seeking end of our magnetic needle must really be a south-pole, since it is attracted by the north magnetic pole of the earth. Unlike poles attract each other.

As man learned more about the earth he began to wonder why it should be a magnet. Of course, there is a good deal of iron in the earth's crust and perhaps a great deal more in the interior of the earth. Since man has never been able to dig more than two miles down into the earth, no one really knows with certainty what its interior is like. Even if the earth is largely made of iron, as some believe, there is still the question of how the earth's iron became magnetized. An entirely satisfactory answer to this question has not been found, though many of the answers are very interesting. If you would like to read about some of these explanations, look up the references given on pages 198 and 199.

Though we do not know exactly why the earth is a magnet, we can learn a great deal about its behavior as a magnet. Frequently, in the history of science, we have discovered true causes by studying closely the way in which things behaved. By observing more and more closely the magnetism of the earth we may some day learn why the earth is a magnet.

The earth, as you know from your study of geography, is rotating—spinning like a top. The ends of the axis around which it spins are called the north and south poles. When Peary discovered the North Pole, he found one end of the earth's axis—the geographic north pole. When Amundsen discovered the South Pole, he found the other end of the earth's axis—the geographic south pole. It might have been very convenient if the earth's magnetic poles were in the same places as the geographic poles. However, the magnetic poles are a long way from the geographic poles—several hundred miles in fact. Yet, where we live, the

difference between pointing to the geographic north and pointing to the magnetic north is not very great.

Small as this difference is, captains of ships must take it into account in order to direct their ships properly. To navigate accurately the captain must know exactly where the magnetic pole of the earth is. Furthermore, his task of navigation is made still more difficult by the fact that the positions of the magnetic poles change from time to time. The sun seems to affect the magnetism of the earth; for a compass needle changes its direction slightly from sunrise to sunset. Also, the season of the year has some effect, as does the number of sun-spots on the surface of the sun. Occasionally, a volcanic eruption will produce a change in the position of the earth's magnetic poles; and electrical disturbances in the air will often cause "magnetic storms" which affect the direction of the compass needle.

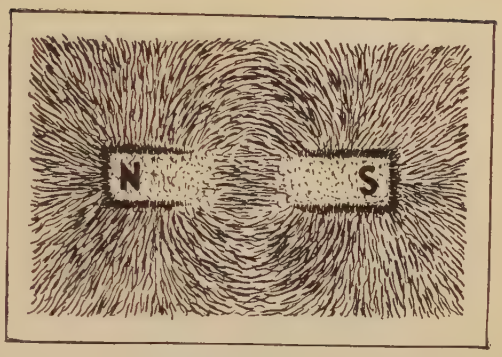
Many of these changes occur regularly and navigators can therefore count on them. Some of the changes, however, are sudden; and so expeditions are sent out again and again by governments to chart the new positions of the earth's magnetic poles.

When Columbus set out on his great voyage of discovery he depended a great deal on his magnetic compass. Whenever clouds covered the sky at night, so that he could not see the North Star, he watched his compass, which pointed in the direction of the North Star. However, as he sailed on for thousands of miles, he was surprised to find that the compass did not point exactly to his guiding star. This puzzled him greatly. When his men learned of this, they became frightened and wanted to turn back. Not knowing the real cause, Columbus told them that the North Star was changing its position, and they believed him. Evidently, his men had greater confidence in the magnetic compass than they had in the regular motions of the heavenly bodies.

9. The magnetic force of the poles of a magnet is exerted in a region near the magnet, called the magnetic field

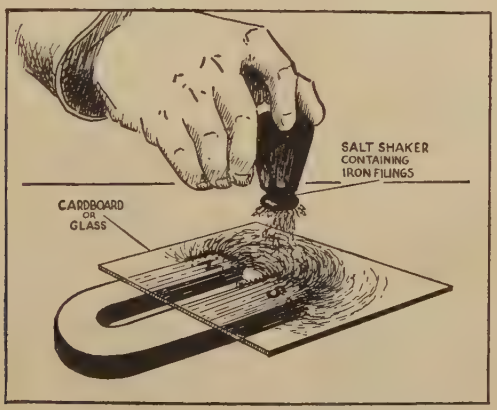
The closer you bring a piece of iron to the poles of a magnet, the more strongly will the magnet attract it. If you were to place a very small speck of iron (no larger than the period at

the end of this sentence) near a magnetic pole, it would move to the pole. The path that the speck of iron would take would not be a straight line, but a curved line, even though the curved path is longer. These curved paths are called *lines of force;* and the region occupied by these lines of force is known as a *magnetic field.*



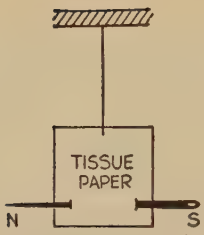
15. Magnetic field around a bar-magnet.

If you would like to see specks of iron arrange themselves along lines of force, try this experiment: Prepare some iron fil-

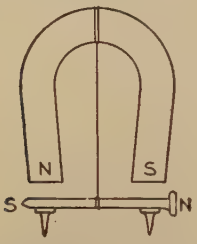


16. Magnetic field around a horseshoe magnet.

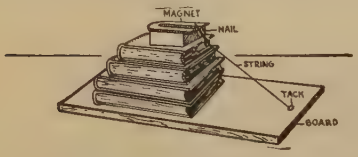
ings and place them inside a salt-shaker. Lay a sheet of paper over a bar-magnet and sprinkle iron filings over the paper from the salt-shaker. As you tap the paper gently with a pencil you will see the filings arrange themselves in curved lines, some of which reach from one pole to the other. See figures 15 and 16.



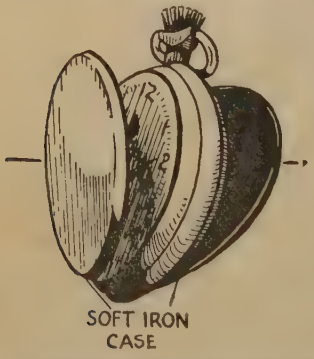
(*a*) A simple kind of magnetic needle. Make one.



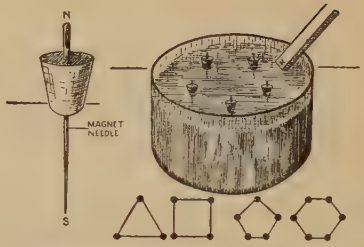
(*b*) Induced magnetism. Will your magnet hold the tacks to the nail at a distance of one-half inch?



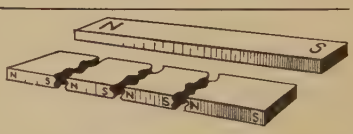
(*c*) Try this experiment. See how long you can make the string.



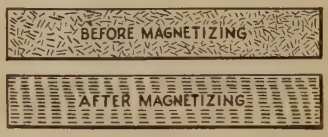
(*d*) Of what use to the watch can the soft-iron case be?



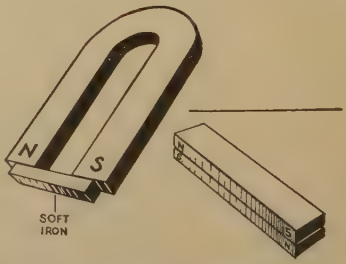
(*e*) "Mayer's needles." Try them out



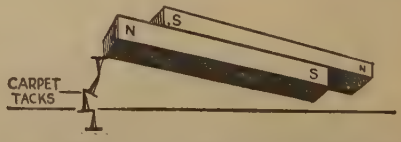
(*f*) One magnet becomes four magnets! Write out your explanation for this.



(*g*) This picture suggests a theory to explain magnetism. Can you state it?



(*h*) When you store magnets away, do as shown in this picture. Why?



(*i*) When the N-pole is opposite the S-pole, the tacks will fall off. Why?

17. PROBLEM PICTURES

HOW MUCH DO I REMEMBER?

Each of the numbered statements below is incomplete; but with each are listed several possible completions. Select the most correct. Write your answers on a sheet of paper so as not to mar the book.

1. It is certain that magnetism was discovered

   (a) by the shepherd, Magnes; (b) by the ancient Chinese; (c) in Magnesia, Asia Minor; (d) many hundreds of years ago.

2. A lodestone is

   (a) a piece of magnetic iron ore; (b) a shepherd's stick; (c) a piece of steel.

3. Magnets attract objects made of

   (a) anything; (b) any metal; (c) iron or steel only; (d) silk and cotton only.

4. A magnet can be used for lifting

   (a) a penny; (b) a pen-point; (c) a checker; (d) a piece of glass; (e) a skate key.

5. Every horseshoe magnet is

   (a) a natural magnet; (b) an artificial magnet; (c) an electromagnet; (a) a bar-magnet.

6. A permanent magnet must be made

   (a) in the shape of a horseshoe; (b) in the shape of a bar; (c) of soft iron; (d) of hard steel.

7. The best way to magnetize a knife-blade strongly is to

   (a) wind an electric wire around it; (b) rub it on the end of a magnet; (c) hold it near a magnet; (d) insert it into an electromagnetic coil.

8. You can destroy the magnetism of a knife-blade by

   (a) induction; (b) rubbing many pieces of steel on it; (c) heating it.

9. A magnet will attract most strongly

   (a) in the middle; (b) at either the north pole or the south pole; (c) at the south pole; (d) at the poles when they are bent over so as to be near each other.

10. A magnetized needle, suspended freely, acts as a compass because

    (a) the earth pulls all things to itself; (b) the earth is a magnet; (c) the North Star attracts it; (d) unlike poles attract each other.

11. The magnetic poles of the earth are

    (a) always at the geographical poles; (b) always in the same places but not at the geographical poles; (c) are constantly shifting their positions in regular fashion; (d) are constantly shifting their positions but not always in regular fashion.

12. The north-seeking pole of a compass is the same as its

    (a) North pole; (b) South pole; (c) south-seeking pole.

13. The earth's magnetism is due to

    (a) electricity; (b) sun spots; (c) iron deposits; (d) causes which are not yet fully understood by scientists.

14. Columbus' compass did not point exactly to the North Star because

    (a) the North Star changed its position; (b) the earth's magnetic

and geographical north poles are not at the same place; (c) evil spirits were at work.

15. A magnetic field is

(a) a place where natural magnets are found; (b) the region between and about the poles of the magnet; (c) a lot of iron filings sprinkled around a magnet.

LET US TALK THINGS OVER

You have begun your study of magnetism. In class you have seen your teacher perform several experiments and at home you have read the first chapter of this book. In class you and your friends have discussed with your teacher the strange ways of magnets, and possibly at home you have tried to do some of the experiments to see if they really work. We hope you have begun to build your laboratory by collecting and making the necessary materials. Also, we hope you have been able to answer correctly all the items in the "Remember" test.

If you scored 90% or over in this test you are to be congratulated. We hope you will do so again for the next chapter and for the others which follow. In this way you can make a good beginning in your career as a scientist. But a scientist must go further. He must continue to study and to experiment. As a matter of fact, he cannot help doing this; for one experiment leads to another and every fact he learns raises another question.

Let us take the subject of magnetism as an example. You have learned that a magnetized steel bar has two poles, one near each end. Suppose now, that you magnetized a steel ball—Where would the poles be? Again, you have learned how to magnetize a steel spring so that one end is a north pole and the other a south pole. Now suppose you wished to reverse the poles—Could you do it? How?

There are hundreds of interesting questions, all requiring study and experimentation. To answer them all we should need to make this book a hundred times longer than it is. We believe that there is more fun to be had and more to be gained by finding out about these things yourself.

How does a scientist proceed to find out about things? He employs two methods. First, he tries to find out if any one

already knows the answer to his question. The simplest way of doing this is to read the writings of other men of science. Of course, he need not believe everything he reads. Many books have been found to be wrong. Yet, he can learn a good deal from some one else's experiments; particularly if he has confidence in the writer and knows the latter to be a careful thinker.

And SECOND, he can arrange his own experiments to check the conclusions of others; or, if no one knows the answer, he can try to discover it himself. This is by far the better method; for it leads to new facts, new discoveries, new inventions and new experiments.

At this early stage in your career as a scientist, you should make use of both methods. To help you do this, every chapter of this book will close with two lists. One, a list of *Things to Think About and Find Out About* and the other a list of *Things to Do and Make.*

The first list will raise many interesting questions. It will show you that there are many other things to learn about the subject of the chapter. What you have read is only a beginning. Pick out one question that interests you very much and set out to find an answer. Perhaps, when you have discovered the answer, your teacher will let you report it to the class. If you have the time try another. As you continue to do this, you will learn to read books and to use books of all kinds. You will become familiar with the use of the *Index* and the *Table of Contents.* You will find that it is easy nowadays to learn a good deal about most subjects in science from those who have written about their experiments in books. To help you with our list of questions we have given a number of books which you will enjoy reading. This list you will find on pages 198 and 199. Many of these books are in your class or school library. Others of them you can borrow from the public library.

The second list will suggest interesting experiments for you to perform. Since you will need some assistance and direction in carrying out these projects, we have selected ten books of scientific experiments. Every science classroom should have several of these books, so that they may be borrowed and used by the pupils.

Here they are:

A. Electrical Amusements and Experiments, by Gibson (Lippincott).
B. Scientific Amusements, by Tom Tit (Nelson).
C. The Boy Electrician, by Morgan (Lothrop, Lee and Shepard).
D. Boy's Book of Experiments, by Collins (Crowell).
E. The American Boys' Book of Electricity, by Seaver (David MacKay).
F. How To Make Things Electrical, by U. P. C. Book Co., 250 Fourth Ave., New York City.
G. Electrical Toy Making, by Sloane (Henley).
H. Boy's Home Book of Science and Construction, by Morgan (Lothrop, Lee and Shepard).
I. Electro-Craft, by Baxter (Bruce).
J. The Book of Electricity, by Collins (Appleton).

Note the letters, A, B, C, etc., which label the ten books in this list. We will refer to the books by their letters. Thus, "Book A, page 12," means that directions for performing a certain experiment will be found in Book A beginning on page 12.

And now, let us look at the list of questions for the subject of Magnets and Magnetism.

THINGS TO THINK ABOUT AND FIND OUT ABOUT

1. What is a dipping needle?
2. How may compass-needles be used to help locate deposits of iron ore?
3. Find out what other metals than iron are affected by magnets.
4. What are the "northern lights"?
5. When you break a magnet in the middle why do the broken ends act like magnetic poles?
6. A science teacher found that some sand became mixed with his iron filings. How might he separate the filings from the sand?
7. What is meant by "boxing the compass"?
8. What do people mean by the expression, "He has a magnetic personality"?
9. If a steel ball is magnetized, where will its poles be located?
10. How would you find out if there is iron dust in the air of the subway?
11. Prove that the earth is a magnet.
12. When the pillars supporting an elevated railroad are removed, they are found to be magnetized. Why?
13. Who was William Gilbert and why is he famous?
14. How would you identify the poles of an unmarked magnet?
15. How would you reverse the poles of a magnet?

THINGS TO DO AND MAKE

(The letters and page numbers refer to the books listed on page 18.)

1. A spinning iron wheel. It is rotated by a magnet and a candle flame.
   Book B, page 326; Book G, page 204.
2. "The Hand of Mystery." This is a magnetic toy which answers your friends' questions. The fun you get from this will repay you for your effort.
   Book A, page 19.
3. A rolling armature, Mahomet's Coffin, magnetic jack straws, a magnetic top and a magnetic pendulum.
   Book G, pages 23 to 34.
4. How to make a magnetic compass.
   Book I, page 114; Book J, page 29; Book H, page 326.
5. How to make a magnetic dipping needle.
   Book C, page 14.
6. How to make a permanent magnet.
   Book J, page 29.
7. A magnetic fishing pond.
   Book A, page 64; Book G, page 35.

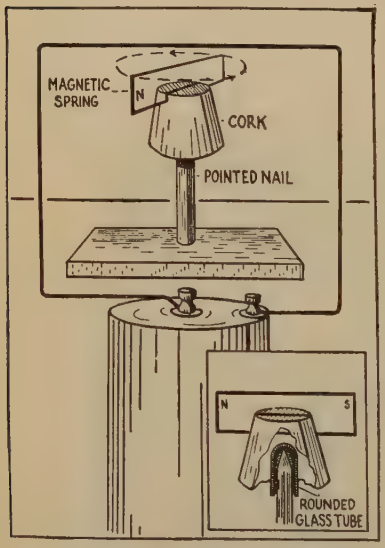
Materials for experiments with magnets.

CHAPTER II

ELECTROMAGNETS

In the year 1822, a professor of science in the far-off land of Denmark stood before his students, talking to them about the latest experiments with electricity. Electricity was then a new and mysterious force. Very few men knew anything about it. One had to go to college to learn even a little bit about it. To expect an eighth grade boy to know about electricity was unheard of at that time.

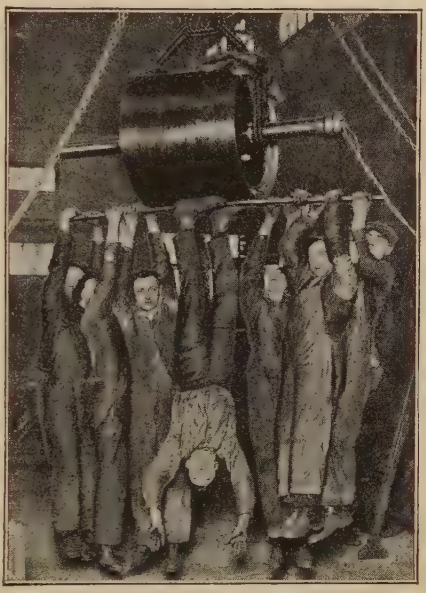
Now, it so happened that on the table at which this professor was standing was a magnetic compass needle. Probably, the professor had forgotten to remove it after a previous experiment. At any rate, the compass was there, and was close to a wire that he was just about to connect with an electric battery. All eyes were watching his movements. As he made the connection something happened in the apparatus with which it was connected; but we have never been able to find out what that was, because everybody's attention was drawn to something else. This something else was the compass needle. It moved. This was very strange. No one had expected it. The compass needle was there by accident. The experiment the professor was performing had to do with an entirely different matter; and yet, the flow of elec-



18. Oersted's experiment. Magnetic compass changes its position when current flows through wire.

tric current seemed to affect the magnet. See figure 18. Everybody was so surprised that he forgot the experiment the professor was really showing and began to raise questions about this strange behavior of the magnet.

The name of this professor was Oersted and his discovery marks the birth of electromagnets. Oersted was the first to show that when electricity flows through a wire, the wire will behave like a magnet so long as the current flows through it. Now you know who is responsible for the method of making temporary magnets with electricity. See figure 8.



19. What kind of shoes is the inverted man wearing? Approximately how many pounds is the electromagnet holding?

Oersted's discovery was taken up by others. An American scientist, Joseph Henry, soon showed how to take advantage of a "magnetic" wire. He wound the wire into a coil, thus concentrating the magnetic strength within the hollow of the coil. In 1831 Henry coiled a wire several miles long and sent a current through it. Near this coil he poised a magnet in such a way that whenever he sent electricity through the coil the magnet would move so as to ring a bell.

This experiment of Henry's created a sensation. All the newspapers wrote about it, very much as they do to-day about television. As we shall see in the next chapter, Henry's experiment inspired Morse to invent the telegraph.

Another of Henry's sensational experiments at about the same time was to wind a coil so large that it would lift 3500 pounds of iron when a large amount of electricity was sent through it. The coil itself weighed about 100 pounds.

Out of these simple beginnings, the electromagnet has developed so rapidly and has assumed so many different forms and uses, that in the course of a day all of us meet with such magnets hundreds of times. Let us see how life to-day brings us in contact with electromagnets.

When we get up in the morning, we wash in water which is pumped to our homes by machines the most important part of which is an electromagnet. Soon, the dumbwaiter bell—an electromagnet—rings to announce the arrival of ice. The gas which is burned to cook our breakfast is forced into storage-tanks by pumps using electromagnets. When the postman arrives with mail he announces himself by operating an electromagnet. You descend from your apartment in an elevator driven by electromagnets. As you walk through the streets you see on every side automobiles and buses in which electromagnets are necessary to furnish electric sparks. You board a trolley, elevated, or subway car which is driven by an electromagnetic device called a motor. The light by which you read your newspaper in the subway is generated by electromagnets. Ventilation of the car in which you ride is furnished by fans driven by electromagnets. The signal system which makes for your safety in the subway is based on the operation of electromagnets.

In school, there are bells and gongs operated by electromagnets; and your classrooms may be ventilated by fans driven by electromagnets. The principal telephones messages to the teachers with an instrument which utilizes the electromagnet.

When you walk through city streets you notice fire-alarm boxes which operate by means of electromagnets. You see large electric signs whose power is supplied by electromagnets. You pass windows in which are displayed typewriters that write messages by means of electromagnets. Various interesting devices and rotating displays are set in motion by electromagnets. Now you see a shoe-repair shop in which dozens of wheels are kept spinning by electromagnets. Next door you see a barber-shop pole busily attracting attention through the use of electromagnets. Traffic signals are kept going by electromagnetic devices. If you step into a restaurant, drug-store, or ice-cream parlor drinks are mixed and oranges are squeezed for their juice with

electromagnetic machines. When you pay your bill an electromagnet in the cash register will record the sale. If you order a meal in a modern restaurant you should know that your food has been kept cool, and your dishes washed with machines, operated with electromagnets.

At home you use the telephone, the sewing machine, the vacuum cleaner, the player piano, and the radio—all devices in which electromagnets play an important part.

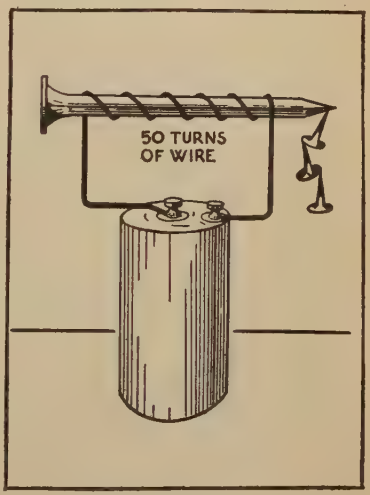
When you go to the theatre, the motion-pictures, the "talkies," the stage curtains and scenic effects as well as the intricate signal system all depend on electromagnets. Even the air is cooled with a device which includes electromagnets.

Finally, much of your clothing, your food, and other necessities is to-day manufactured, transported, and distributed with the aid of electromagnets.

1. The essential parts of an electromagnet

In order to make an electromagnet, you need (1) insulated wire, (2) a *source of electric current*, and (3) some kind of *core* around which to *coil* the wire.

In any hardware shop you can buy some large nails and a spool of insulated wire. Ask for enameled wire, for it is cheap. On this wire is a coating of enamel paint instead of rubber or cotton, to keep the bare wire from touching other bare wires. Take about 10 feet of wire and wind it around the nail. Scrape the insulation from the ends of the coil and connect them with a cell (battery). See how many iron nails you can lift with this electromagnet. See figure 20.

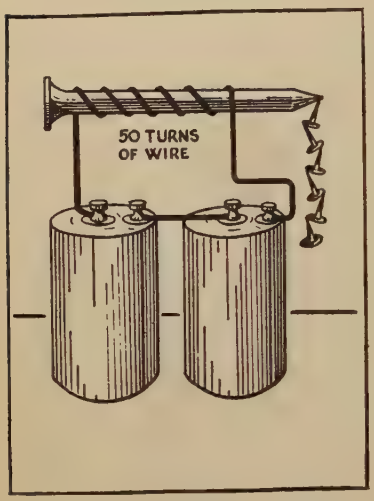


20. How many tacks will your electromagnet hold?

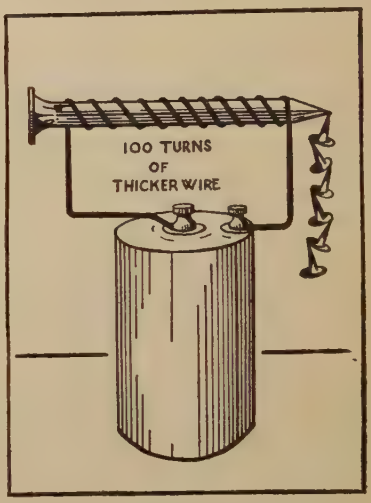
2. The greater the current the greater the magnetic attraction

Take the same coil, which you have just wound, and having

connected it with one cell see how many nails of equal size it will hold. Connect it with two cells. How many can you hold now? If you have three cells, try the experiment with three



21. The more current, the greater the attraction.



22. The more turns, the greater the attraction.

cells. Try it with as many cells as you have. Join forces with a friend or classmate and see how strong a magnet you can make. See figure 21.

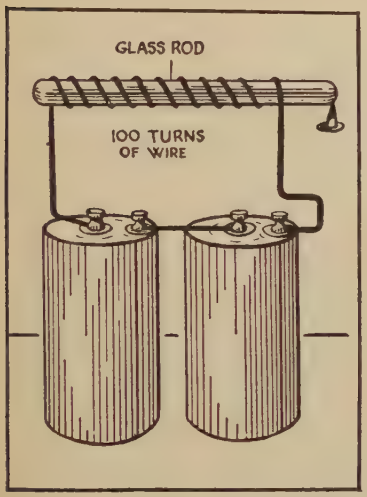
3. The greater the number of turns, the greater the magnetic attraction

If you haven't more than one or two cells you can increase the strength of your electromagnet in another way. Wind 20 feet of thicker wire around your nail instead of 10 feet. Then wind 30 feet, 40 feet, 50 feet and so on. In each case, connect only one cell and count the largest number of nails which your electromagnet will hold. See figure 22.

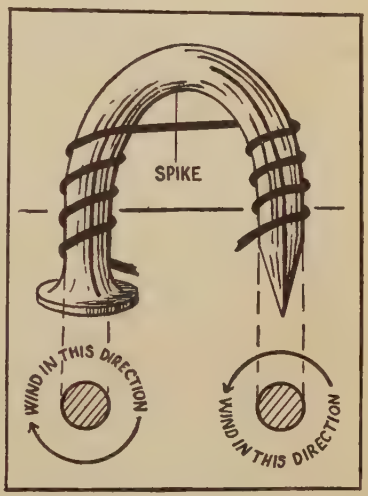
4. A soft iron core increases the strength of an electromagnet

Instead of winding your coil around an iron nail, try winding it around a glass rod or a piece of wood. See figure 23. Does your electromagnet lift anything now? In doing this experiment

use about fifty feet of wire and as many cells as you can get. In this way, you may succeed in lifting nails with an electromagnet that has a wooden or glass core. With a soft iron core, however,



23. A soft-iron core increases the strength of an electromagnet.



24. How to wind an electromagnet.

you will get the greatest magnetic attraction. If you have a steel rod (use a knitting needle) you might compare its strength with that of soft iron when used as a core in the same coil and with the same amount of current.

5. The action of an electromagnet resembles that of a bar-magnet

Make an electromagnet in the usual way and then immerse it in a heap of iron filings. Tap it gently. Do you notice that the electromagnet has *poles?* Only near the ends does the attraction seem to be great.

Take one of your unbent electromagnets and hold one pole near the north-seeking end of a compass needle. (Use your floating compass.) Is there an attraction or a repulsion? Try the other pole of your electromagnet. Since an electromagnet behaves like a bar-magnet you should be able to find out which end of your electromagnet is north-seeking and which south-seeking.

Just as in bar-magnets, like poles repel each other, and unlike poles attract each other.

Do you remember the experiment in which you placed a magnet under a sheet of paper and scattered iron filings over the paper? See page 13. See if an electromagnet can be used in this experiment in place of the bar-magnet. Does an electromagnet have a *magnetic field?*

Since an electromagnet has *poles* we might take advantage of its strong parts as we did in the case of a bar magnet. Let us therefore bend the nail into a horseshoe so as to bring the poles closer together. This will concentrate the magnetic strength. Furthermore, why waste the turns of wire around the middle of the horseshoe? Suppose, then, you first bend an iron nail into a horseshoe and then wind the wire around its ends only. You will find that most electromagnets are wound in this way. See figure 24 to help you in winding your electromagnet.

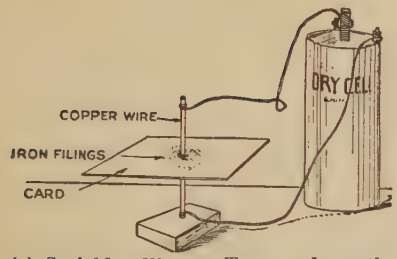
6. An electromagnet is more useful than a bar magnet

If an electromagnet behaves exactly as a bar magnet does, why go to the trouble of making electromagnets? You can find an answer to this question if you will do these experiments.

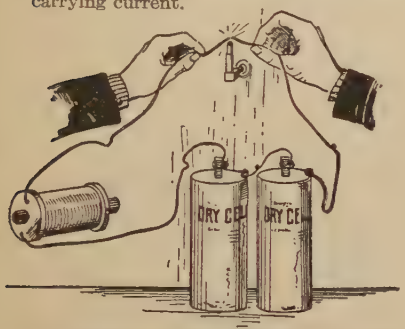
Connect one of your electromagnets with two cells. Let us suppose it can then lift five nails. If you wish to lift more nails, all you need do is to connect the coil with three or more cells. If you wish to lift fewer nails, use only one cell. If you wish to lift none at all, disconnect your coil. Thus, you can change the strength of an electromagnet at will, either by changing the amount of electric current or by changing the number of turns in the coil. A bar-magnet has a fixed strength, which can not be so readily changed.

The recent changes in loud speakers for radio sets show how useful this variability in strength may be. In the beginning permanent magnets were used in all loud-speakers. Now, most of the better speakers are equipped with electromagnets, which enable us to produce a better quality of tone with much greater volume.

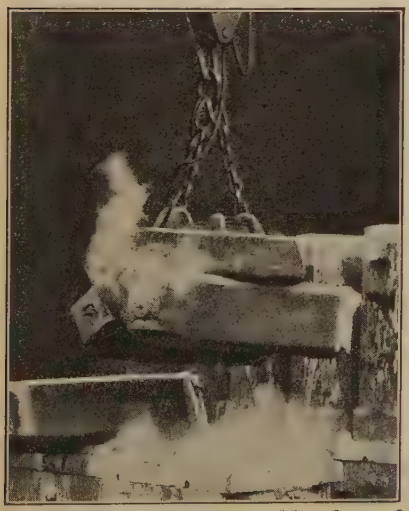
Another advantage which an electromagnet has over a bar-magnet is that a north pole can be readily changed to a south



(*a*) Sprinkle filings. Tap card gently. Study the magnetic field around a wire carrying current.

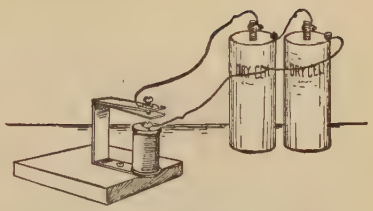


(*c*) The spark will light the gas. Try it on the gas-stove in the kitchen.



(*d*) Electromagnet lifting red-hot bars of iron. Will the bars fall when the magnet core gets red hot? Why?

25. PROBLEM PICTURES.



(*b*) Make this buzzer and bring it to class.

pole and a south pole to a north pole by changing the direction in which the current flows. In a bar-magnet this is difficult to do.

Using one of your electromagnets, bring its north-end close to a south-end of a floating compass needle. Of course, there will be an attraction. Now, interchange the connections at the battery so that the current will flow through the coil of your electromagnet in the opposite direction. What happens? The compass needle is repelled and moves away; therefore you have changed the north-end of the electromagnet to a south-end.

This ability of an electromagnet to change its poles is very useful in the electric motor. In fact, an electric motor will not turn unless one of its electromagnets, the *armature*, changes its polarity every half turn.

HOW MUCH DO I REMEMBER?

A

Supply the missing parts for the following statements. Write your answers on a sheet of paper so as not to mar the book.

1. When electricity flows through a wire, the wire will behave like a .....
2. The first man to show this was .....
3. Joseph Henry concentrated the magnetic strength of a wire by winding it into a .....
4. A magnet which is produced by electricity is called .....
5. In order to make an electromagnet you need (1) ....., (2) ....., and (3) .....
6. If your electromagnet is to be as strong as possible, the core should be made of .....
7. The attraction of an electromagnet is strongest at .....
8. An electromagnet can be made in the shape of either a bar or .....
9. In the case of electromagnets, unlike poles ..... each other and like poles ....
10. The region near an electromagnet where the magnetic force of its poles is exerted is called .....
11. The only kind of magnet whose strength can be changed at will is .....
12. The most powerful magnets are of the ..... type.

B

Below are 10 *numbered statements. For each of the ten pick out one statement in the second group of five which best explains it.*

Statements:

1. Joseph Henry was able to demonstrate electromagnetism more effectively by coiling a wire several miles long.
2. Henry's coil could lift 3500 pounds of iron when a large amount of electricity was sent through it.
3. The nail refused to stick to the bend of the horseshoe magnet.
4. This electromagnet is too weak. Connect an extra dry cell to it.
5. The north pole of the compass pointed to the end of the coil through which electricity was flowing.
6. Practically no filings stick to the middle of the coil.
7. A nail makes a better core for an electromagnet than a knitting needle.
8. The presence of electromagnets in an airplane affects the compass.
9. The electromagnet picked up nails as well as iron filings. I removed a good deal of the wire and it now lifts only the filings.

10. A floating compass-needle was attracted to an electromagnet. The current in the magnet was reversed. Immediately the compass rotated through half a circle.

Explanations:

A. Magnetic attraction is greatest at the poles.
B. Unlike poles attract each other; like poles repel.
C. The greater the current, the greater the magnetic attraction.
D. The greater the number of turns, the greater the magnetic attraction.
E. A soft iron core increases the strength of an electromagnet.

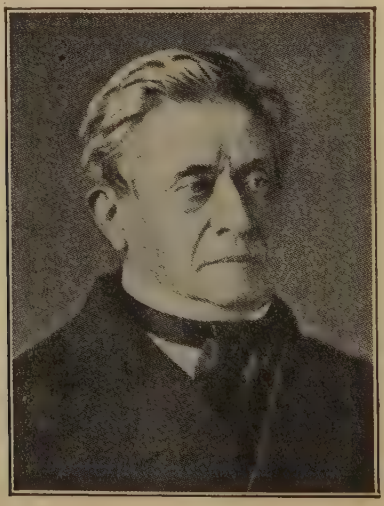
THINGS TO THINK ABOUT AND FIND OUT ABOUT

1. Which of the following devices employ electromagnets? electric motor, hammer, telephone receiver, electric bell, push button, gas stove, phonograph, buzzer, radiator, violin.
2. What is the "right-hand-thumb-rule" by which the poles of an electromagnet may be identified?
3. Why do they use soft iron instead of steel as the core of electromagnets?
4. Is it possible to tell by means of a compass if a current of electricity is passing? How?
5. Does a wire have to be coiled to be a magnet? Why?
6. How is city traffic controlled by means of electromagnets?
7. Make a list of all the devices about which you know, which employ electromagnets.
8. Find out about permalloy magnets.
9. How are electromagnets used on farms? In hospitals? In offices? In factories?
10. Find out about the life and work of Oersted. Of Henry.
11. How can you wind a wire around an iron nail, so that current flowing through the coil will *not* magnetize the nail?
12. During the Great War, a boy wrote to the Navy Department suggesting that large electromagnets be immersed in the ocean in order to attract and hold fast the enemy submarines. What do you think of the scheme?
13. Which would be a stronger electromagnet, one with a soft iron core or one with a steel core? Why?
14. Which would be a stronger electromagnet, one with 100 turns of thin wire or one with 100 turns of thick wire?
15. How would you make an electromagnet with bare, uninsulated wire?

THINGS TO DO AND MAKE

(The letters and page numbers refer to the books listed on page 18.)

1. How to make different kinds of electromagnets.
   Book G, page 37.
2. How to use an electromagnet to detect the flow of electricity.
   Book C, page 126; Book D, page 170; Book E, page 96; Book G, page 179; Book H, page 341; Book I, page 116.
3. The magic hemispheres—a peculiar form of electromagnet.
   Book G, page 42.
4. The obedient doll—a fun-provoking electromagnet.
   Book A, page 43; Book G, page 238.
5. The magic drum—plays at the performer's command.
   Book G, page 76.
6. The mystic nail—A key will hang on a chalk nail you draw on the blackboard.
   Book G, page 241.
7. An electric door-locking device.
   Book G, page 188.
8. A toy cannon—The projectile is driven out by an electromagnet.
   Book F, page 269.
9. How to make an electric stop for a phonograph.
   Book F, page 10.
10. How to use an electromagnet as a battery tester.
    Book F, page 257.



Joseph Henry.

CHAPTER III

ELECTRIC TELEGRAPH AND ELECTRIC BELL

Twelve o'clock. An hour when most people are asleep. Even in our crowded city there comes at this time a quiet, made all the more impressive by the occasional rumbling of a truck on hard pavement. Yet, there are certain spots in the city which at this hour are more fully awake than they are at noon. Times Square, in New York City, is seething with life at midnight. Sidewalks are packed with people. Streets are jammed with automobiles. Overhead is a blaze of light and the air is filled with a roar of sound.

As you wait for a change in traffic lights so that you may cross the street, you look up to see racing across the wall of a skyscraper huge letters of the alphabet. They spell a word; and as word follows word you find that a message is being flashed out to the crowds. A flood in a distant city! War is threatened between two nations! A crime was committed just half an hour ago in another state! The King of England is ill! Our president has just sent a message to congress!

This is news—the latest news—news, up-to-the-minute. It comes from near and from far to a modern newspaper which can tell a story in print or on an electric sign in less than an hour after the actual occurrence.

If you are curious to know how this marvel is accomplished you may go into the skyscraper to observe. You are ushered into a large room where you are overwhelmed by sound. As you become accustomed to the din you find that on all sides of you there are small instruments incessantly clicking. These clicks tell stories, convey messages, ask questions, and bring information from all corners of the earth.

The modern newspaper, so important to every one of us, is dependent on the *telegraph,* which is one of the outstanding

methods of communication in modern life. It represents the first use to which the electromagnet was put in making the life of man more comfortable, more economical, and more interesting.

Until the coming of the telegraph, man's need for communicating with his fellows was met in various slow and cumbersome ways. We read in Greek history of the hero, Pheidippides, who raced back to Athens from the battle at Marathon with the message that his people had won. It took two days and two nights of constant running to convey this message across a distance of about 100 miles. Paul Revere on a horse carried his message not very much more quickly. An automobile, a train, a ship, even an airplane, can improve but very little on the speed of man or of horse.

The sending of signals through puffs of smoke, a method much used by the Indians, was of course effective and rapid, but required elaborate preparation. The Roman method of flashing the sunlight on shields had certain serious limitations, as does communication by the beating of drums. It is only by means of electricity that very great distances can be spanned quickly and signals transmitted practically without error.

Like Oersted's discovery of the electromagnetic principle, the invention of the telegraph was largely accidental. A chance conversation between two men was the stimulus which brought it into existence.

Samuel Morse was an artist—a painter and a sculptor of some prominence. In 1832, shortly after Joseph Henry had exhibited his sensational electromagnet, Morse was returning home from Europe. On board ship he met a Dr. Jackson, who engaged him in conversation. Among the topics discussed was the electromagnet and its behavior. In the course of the conversation Morse was struck with an idea. From that moment on, his talents in art were devoted to sketching ideas for a telegraph system. As he landed in New York, he remarked to the captain: "Should you hear of the telegraph one of these days as the wonder of the world, remember that the discovery was made on board the good ship *Sully*." Five years later Morse filed his patent for the telegraph; but he had renounced his art forever and his private fortune had been reduced to nothing. It took seven years more of

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26. Telegraphing through the ages. Make a list of the methods of telegraphy shown above. Arrange them in order so that the method which spans the greatest distance is first, and so on.

gruelling effort in the face of ridicule, poverty, and discouragement of all kinds before he perfected his device. Finally, in 1844, Morse successfully sent a message from the Supreme Court room of the Capitol in Washington to Baltimore. This famous message, "What hath God wrought!" marks the birth of the telegraph. When he died in 1872, Morse was a rich and prominent man, and the country was covered with a network of telegraph wires carrying messages from city to city. He bequeathed to mankind a device which many people believe is more valuable than any paintings or pieces of sculpture which he might have left, had he continued in his earlier career.

Of course, the telegraph has been improved since Morse's time. Edison had a share in this improvement when he found a way of sending four messages at a time over the same wire. Hughes, Rowland and others invented several devices which automatically receive telegraph messages and type them on a moving paper ribbon. Since 1904 experiments have been in progress to perfect the sending of pictures by telegraph. The telephone and the radio have recently displaced the telegraph in this field of communication. In the field of news and in the business world, however, the telegraph is still of tremendous importance.

TELEGRAPHING ACROSS THE OCEAN

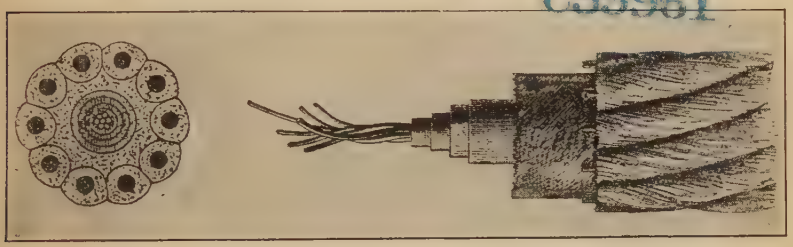
It is a tribute to Morse's prophetic vision that even before he perfected the telegraph, he spoke of the time when men would communicate by wire across the Atlantic Ocean.

In 1852 Cyrus Field, a retired merchant, became obsessed with the idea of laying a cable across the sea. Devoting all his time, effort and money to the project he succeeded in interesting the American and English governments. Each of the countries lent him its largest battleship for the task. Field and his friends supplied half a million dollars. 2500 miles of cable were coiled up on the *Niagara* as she steamed away from the Irish coast. 400 miles out to sea the cable snapped and with it went all the money and effort.

Not at all disheartened, Field tried again. This time, he devised improved machinery for paying out the cable. He de-

cided also to load each ship with half the cable, have them meet in mid-ocean, splice the cable and lay it in opposite directions to the two continents. After a week of terrific storms which nearly wrecked the ships, they met in mid-ocean. The cable was spliced and they started to sail away from each other, paying

C59961



27. A piece of one of the earliest Atlantic cables.

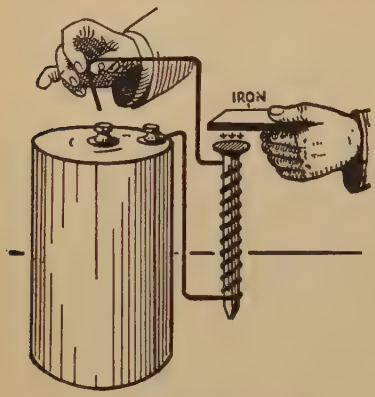
out the cable. When they were three miles apart the cable snapped. They returned and made a new start. This time they had laid 50 miles of cable before it snapped. Undaunted they made a third attempt only to have the cable snap after 200 miles had been laid.

Though most of the stockholders in the scheme were now thoroughly discouraged, Field persisted. Another attempt was made and the precious cable was finally laid. In 1858, Queen Victoria and President Buchanan exchanged greetings across the ocean by means of the telegraph. In the midst of the celebration which marked this achievement an ignorant electrician burned out the insulation and ruined the cable after only a month of use.

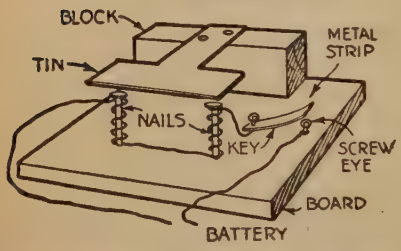
One would expect such a series of mishaps to discourage any mortal, but not Cyrus Field. In 1865 he organized another company. After laying more than two-thirds of the cable, the machinery of his ship broke down and again the cable parted. By this time Field was accustomed to disappointment; his courage was as great as ever. A year later found him at it again with a new company and a new ship. The cable was successfully laid in two weeks. Since July 27, 1866, the world has never been without transatlantic telegraph service.

1. The essential parts of an electric telegraph

If we examine an electric telegraph, we find, first, a *source of current*. This may he supplied from a battery or from a dynamo. In order that the current may flow, there must be a complete path from and to the source. This is usually provided by a *circuit* of copper wires. To start and stop this flow of electricity, there is a switch which, when closed, completes the path and when released opens it or "breaks the circuit." This switch we call the *sender*. Finally, we find in the telegraph a device which uses the flow of current to produce a click. This device is called the *sounder*.



28. How a telegraph works.



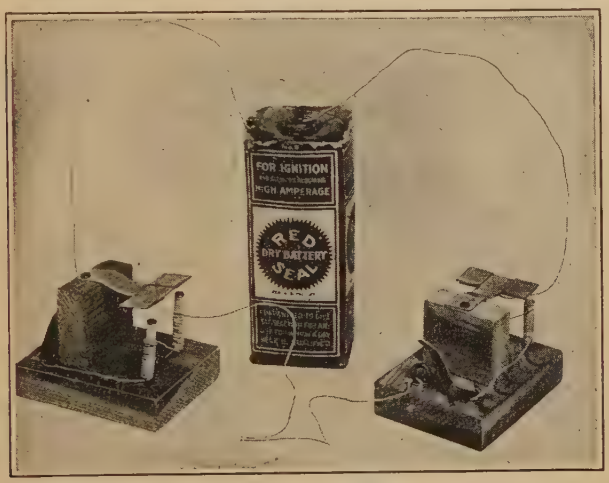
29. A telegraph set any pupil can make.

Thus, *source of current*, *circuit*, *sender* and *sounder* are the essential parts of a telegraph.

Telegraphs are so easy to make and so interesting to play with that every boy and girl should have one. Do you remember the electromagnet which we urged you to make? See page 7. Set it up in a vertical position as shown in figure 28 and hold over it a strip of tin (galvanized iron). Every time you make the connection with the battery the strip of iron will be attracted to the electromagnet. It comes down with a click.

Using the idea shown in this experiment you can now make a real telegraph. In figure 29 you can see how it is done. Go into partnership with a friend or a classmate and have him make one too. Connect your outfits as shown in figure 30. The wires leading from one set to the other may be long. The stronger the current and the more wire you have used in winding the electromagnets, the better your telegraph will work.

Before you can send messages to your friend, he must close his switch. The only break in the *circuit* is your own switch or *sender*. When you press it the current flows through your set and also through his set. The electromagnet, or *sounder*, in each set will attract the iron strip poised over it and draw it down upon the nails with a click. When you release your sender, the magnetic attraction will disappear and the strips will spring back.

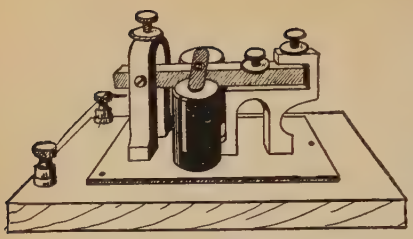


30. How two pupils can connect their homemade telegraphs for communication.

In a real *sounder*, see figure 31, a spring usually helps to pull back the iron strip. The clicks and the intervals between clicks are translated by the listener into letters, words, and sentences.

To listen to your friend's message you must keep your sender closed and let him make and break the circuit. Of course, in order to understand each other you must invent a language or a *code*. When Morse invented the telegraph he also invented the Morse Code. If you wish to learn this code you and your friend must study figure 32 very carefully.

If the Morse Code is too difficult for you to learn quickly, try the scheme shown in figure 33. For example, if you wish to send the letter "L," click twice, pause, and then click three times. The letter "L," you see, is in the second column and third row. In the



31. Telegraph key and sender.

A •–	B –•••	C –•–•	D –••	E •
F ••–•	G ––•	H ••••	I ••	J •–––
K –•–	L •–••	M ––	N –•	O –––
P •––•	Q ––•–	R •–•	S •••	T –
U ••–	V •••–	W •––	X –••–	Y –•––
		Z ––••		

32. The Morse code. Learn it.

same way the letter "P" is sent by clicking once, and then four times. Between words you pause for a longer time than between letters. At the end of sentences you send a long series of clicks.

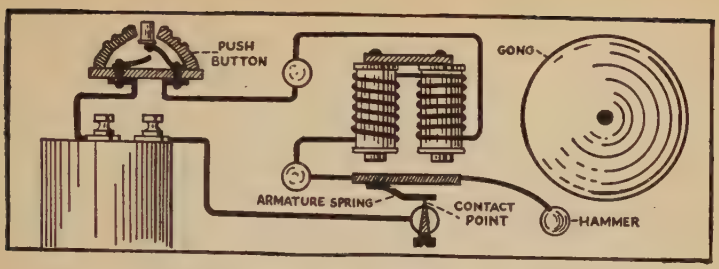
2. The essential parts of an electric bell

If you understand the telegraph you should be able to understand how an electric bell works. Somewhere in your home you will find an electric bell. Take off the square box-cover and examine the inside of the bell. Perhaps the bell in your house has no cover. If so, it will be easier for you to examine. You will find first, two *electromagnet* coils. The core of these coils is an iron rod bent into a horseshoe so that one end goes through one coil and the other end through the other coil. Near the ends of the iron core is a *vibrating strip with hammer attached*. The hammer will strike the gong when it moves. See figure 34.

0	1	2	3	4	5
1	A	B	C	D	E
2	F	G	H	I	J
3	K	L	M	N	O
4	P	Q	R	S	T
5	U	V	W	X	Y
6	Z				

33. A code that requires no memorizing.

To ring a bell you push a button. The button is really a switch and when you push it you complete the *circuit* so that electricity can flow through the electromagnets. These magnets then pull over the vibrating strip because to it is riveted a piece of iron.



34. Parts of a bell and push button connected with a cell.

As it moves over, the hammer strikes the gong; but the vibrating strip in moving over breaks its contact with a screw-point. The current then ceases to flow and the coils lose their magnetism. The iron is, of course, released and returns to its original position. This makes contact with the screw-point again and once more the current flows. Again the coils are magnetized and the gong receives another blow, after which the vibrating strip returns. This happens very rapidly and repeatedly. In fact, with one brief push on the button, the vibrating strip may fly back and forth from screw-point to coils dozens of times; with the hammer striking the gong each time.

In an electric buzzer, the hammer and gong are omitted. Everything else is the same. See figure 35*d*.

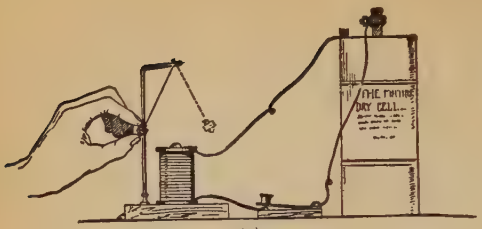
If a bell is made without the vibrating strip you have a "one-stroke" gong.

The one-stroke gongs in your school are really not electric bells at all. They are wound up like clocks. When the spring is released one notch, a hammer strikes a large gong. The release of the spring is caused by the action of an electromagnet whenever the principal or the school clerk closes the switch in the office. This sends electricity through the electromagnets. The clock in the school office can also close this switch at regular intervals, as when the time to change classes arrives.

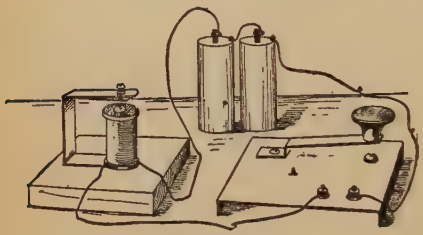
HOW MUCH DO I REMEMBER?

Is each of the following statements true *or* false? *If false, explain why you think so. Write your answers on a sheet of paper so as not to mar the book.*

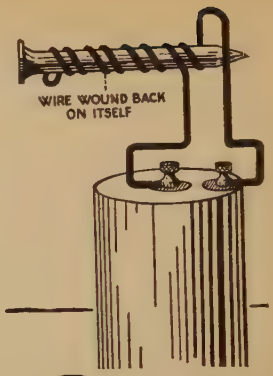
1. The first useful application of the electromagnet was the telegraph.



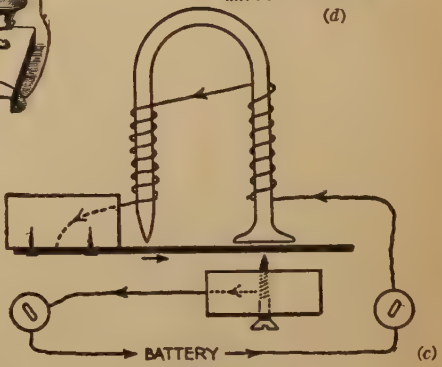
(*a*)



(*b*)



(*d*)



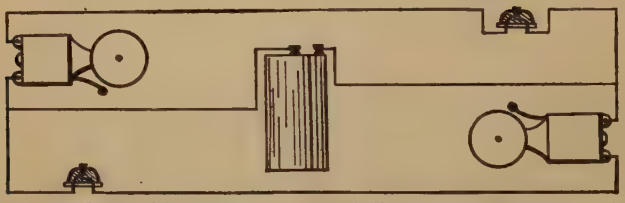
(*c*)

(*a*) A magnetic pendulum. Hide the electromagnet and mystify your friends.

(*b*) A simple telegraph set. Make it with Erector parts.

(*c*) A simple electric buzzer. Make it and bring it to class.

(*d*) How to wind a coil which cannot be magnetized.



(*e*) How you and your friend can connect up bells and push buttons for signalling.

(*f*) A burglar-alarm. Opening the door will ring the bell.

35. PROBLEM PICTURES.

2. Samuel Morse discovered the principle of electromagnetism.
3. The message, "What hath God wrought," sent by Dr. Jackson in 1844, marks the birth of the telegraph.
4. Edison and others shared in the improvement of the telegraph.
5. The radio has displaced the telegraph in the newspaper field.
6. The essential parts of a telegraph are a source of current, a circuit, a sender, and a sounder.
7. The click of a telegraph-sounder is caused by the attraction of an iron strip to the electromagnet.
8. The magnet of a sounder must be a permanent magnet.
9. When the operator closes his sender switch, he causes electricity to flow through the electromagnet of the sounder.
10. The stronger the current the better will be the telegraph.
11. When the sender is released the circuit is broken and the magnetic attraction disappears.
12. To ring a bell you push a button which completes a circuit.
13. In the bell, the circuit is automatically made and broken by the vibrating strip.
14. The telegraph has a vibrating strip like the bell.
15. The "one stroke" gong has a vibrating strip.

THINGS TO THINK ABOUT AND FIND OUT ABOUT

1. How does the street fire-alarm work?
2. How does the school fire-alarm work?
3. How can more than one telegraph message be sent over the same pair of wires?
4. How does the burglar-alarm work?
5. How may the earth be used to save wire in a telegraph system? Make a diagram to show this.
6. Find out how the International Code differs from the Morse Code.
7. Decode the following Morse Code message:

— — — — — ·—· ··· ·
·· — · ···— ·—· — · —··
— ···· ·
— · ·—·· · — —· ·—· ·— ·— —· ····

8. Why does the school fire gong ring only once when the button is pressed?
9. Suppose you pushed the button, but the bell did not ring. How would you go about discovering what was wrong?
10. How does a telegraph relay work? Why is it used?
11. How may ten buttons be connected so as to ring one bell? Show this by means of a diagram.
12. How may ten bells be rung by pressing one button? Show this by means of a diagram.

13. Find out how the signal system for house elevators works.
14. Find out all you can about the life and work of Cyrus Field.
15. Find out about Elisha Gray and his harmonic telegraph.
16. Why must we have a knowledge of the surface of the ocean bottom in order to lay a telegraph cable?
17. Find out how smoke, drums, fires and mirrors have been used in the past for purposes of communication.

THINGS TO DO AND MAKE

(The letters and page numbers refer to the books listed on page 18.)

1. How to make an electric bell.
   Book J, pages 34 and 39; Book E, page 107; Book I, page 70.
2. Useful bell arrangements.
   Book I, page 82.
3. How to make simple push-buttons.
   Book C, page 144.
4. A bell made from odds and ends.
   Book F, page 332.
5. Electric signals for a toy railroad.
   Book F, page 72.
6. Secret bell-ringing circuit—This will eliminate the three knocks for admission to your secret club-room.
   Book G, page 232.
7. A burglar alarm.
   Book C, page 145; Book E, page 110; Book F, page 55; Book G, page 233.
8. Electric insects that flap their wings.
   Book G, page 82.
9. An electric hammer that works like a bell.
   Book G, page 79.
10. How to make an annunciator.
    Book C, page 148; Book E, page 113; Book I, page 126.
11. A sick-room call.
    Book I, page 124.
12. A bell that rings when the room gets too hot or too cold.
    Book F, page 144.
13. An alarm clock which will not stop until you get up.
    Book F, page 58.
14. An imitation of spirit-rapping.
    Book A, page 195.
15. How to make buzzers and telegraph sets.
    Book C, page 154; Book D, page 175; Book E, pages 214 and 362; Book F, page 300; Book G, page 155; Book H, page 363; Book J, page 42; Book I, pages 111, 144 and 146.

CHAPTER IV

CELLS AND BATTERIES

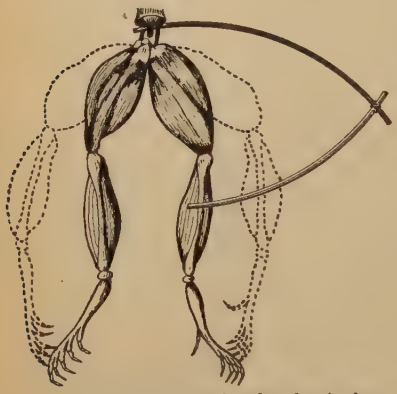
In many of the experiments which we have asked you to perform, you have used cells and batteries. Again and again we have spoken of electricity and electric current. Before we go very much further in our study we should learn as much as we can about electricity and how it is obtained.

The ancient Greeks knew about electricity. It was they who gave it its name. The word *electron* in Greek means *amber*. When amber is rubbed with cloth or fur it becomes capable of attracting small particles to itself. You can observe this strange fact by rubbing a fountain pen on your coat sleeve. After the rubbing it will pick up small pieces of paper. They will stick to the pen as if glued there; it will remind you of a magnet picking up nails. Of course, we cannot say that the pen has become a magnet, since neither the pen nor the objects attracted are made of iron. This attraction must therefore be caused by a different kind of force. Ever since the days of the Greeks, this force has been called electricity.

For two thousand years very little more was learned about electricity. If you had been born a hundred years ago, your study of electricity would not have taught you more than the Greeks knew about it. Then, in the late eighteenth and early nineteenth centuries, Benjamin Franklin and other great men of science began to experiment with this strange force. Franklin in his famous kite experiment showed that lightning was electricity. Other scientists made machines with which substances could be quickly and steadily rubbed, the electric force so accumulated finally flashing through the air like a small bolt of lightning.

The story is told of an Italian scientist—Galvani was his name—who came by accident on a fact which opened to the world a

new field for experimentation. Galvani was experimenting with an electric machine, the kind in which electricity was produced by rubbing. On the table at which he worked were also a number of skinned frogs. It seems that frogs'-legs were at that time thought to be very nourishing for sick people and Galvani was preparing some for his wife who was ill. He went out of the room for a moment, leaving a knife with one end touching the muscle of a frog and the other end touching his electric machine. On returning, he saw the frog's leg under the knife twitching and jerking as if it had come to life. See figure 36. He was astonished. He tried other frogs' legs. The same thing happened. This strange behavior gave him a good deal to think about. Knowing about Franklin's kite experiment, he stretched a long wire from the roof of his house to a distant tree (somewhat like a radio aerial) and connected one end of his aerial wire with a freshly killed and skinned frog's leg. The latter he stuck on an iron railing. During a storm the frog's leg would twitch. Sometimes even in clear weather there would be the same twitching, but long intervals would pass during which no twitching was visible. Then it occurred to him to touch the copper wire, which had one of its ends in the frog's leg, to the iron railing to which it was fastened. To his surprise the leg jumped every time he brought the copper and iron together.



36. How Galvani made the frog's legs jump.

Galvani wrote about his experiments and gave some interesting explanations as to why the frog's legs jumped. To-day we believe no longer in his explanations but we are grateful for his efforts. Another Italian scientist, Volta, was very much interested in the "galvanized" frog's legs and performed some experiments of his own. He found that three substances were essential in producing Galvani's effects; namely, copper, iron and the

fluid in the muscular tissue of the frog's leg. He really did not know what was happening inside the frog's muscle, nor did he know why; but he made a brilliant guess. "The two metals and the fluid are undergoing a chemical action," he said, "a chemical action that produces an electrical force."

Thus was born the idea that electricity can be made to flow by chemical action. Here, then, was a substitute for the rubbing method—perhaps a better method. Volta's next step was to try other metals and other fluids. He obtained the best results with zinc, copper and acids. Since his day, we have found other substances that work even better; but all of our modern batteries are based on Volta's principle. They all contain two metals immersed in a solution. The world has honored Volta by using his name as a unit of electrical measurement. You have all heard of the *volt*. Perhaps you have seen a sign reading "10,000 Volts —Beware!"

Whenever an electrician, a science teacher, or any one uses the word *volt*, he is helping to keep alive the memory of a scientist who benefited all mankind. An even greater honor to the man, however, are the billions of batteries used all over the world, every day in the year.

When you use a flashlight to light your way on a dark country road you are reaping the benefits of Volta's work. Sometimes when you are riding in the subway, the lights go off; but you are not left in total darkness because batteries immediately light up the emergency lights. Automobiles go speeding along dark highways lighting their way with electricity supplied from batteries. Batteries enable you to ring the door bell; and in every telephone station there is a room full of batteries with which to ring the telephone in your home. Miners light their way deep down in the earth with batteries strapped to their backs. Here and there in the city you find trolley cars driven by electricity drawn from batteries and every automobile must have a storage battery in order to start.

Without batteries submarines would not be able to submerge. Until very recently all radios had to be operated with batteries. And these are only a few of the many uses to which batteries have been put. Every day we hear of new ways of using them.

When we see how much our comfort, convenience—even our health and happiness—are dependent on batteries we can hardly understand how people got along before the time of Volta.

1. How Volta's cell produces an electric current

The parts of the simple cell which Volta invented are as follows: *a plate of copper, a plate of zinc* and *sulphuric acid* diluted with water. The acid acts on the zinc. The result of this chemical action is to store up in the zinc plate a certain amount of electricity, which flows into the copper plate when a metallic path is provided from the zinc to the copper. As the current continues to flow, the zinc is gradually eaten away and the copper is covered with bubbles of gas. When the cell is used up there is either no zinc left, or the acid is dried up, or the copper is completely covered with gas. The gas breaks the complete path which is necessary in order that the electricity may flow.

Now, the difficult thing to understand in all this, is *why a chemical action should cause electricity to flow.* It probably puzzles you and it certainly puzzled Volta himself. Volta could offer no really satisfactory explanation. Since his time, many answers have been given, each one better than those that preceded it. To-day, scientists explain the action in a cell in terms of a theory which they call the Electron Theory. It is the best answer to the puzzling question which has yet been given and we believe that any boy or girl can understand it, if he will read carefully, think hard, and ask questions.

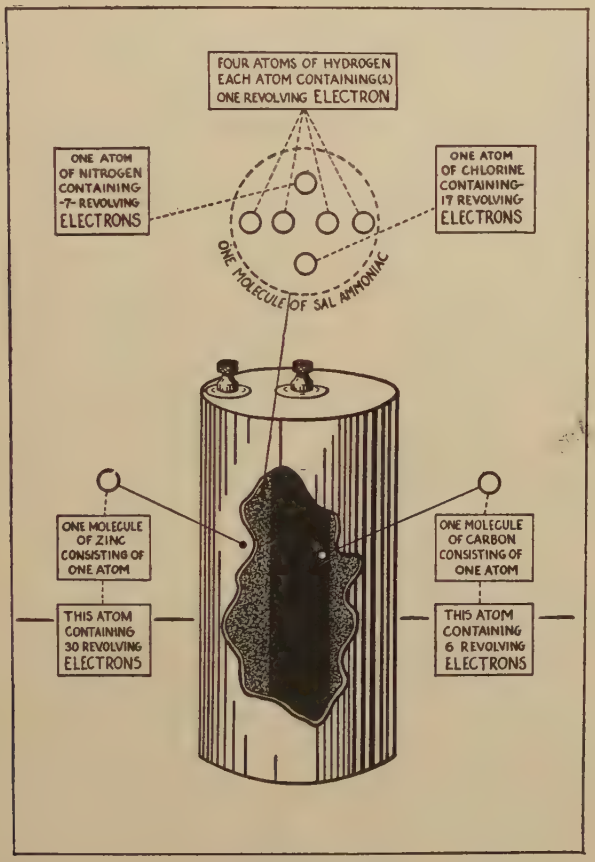
2. A theory to explain Volta's cell

(a) *All substances are composed of molecules*, which are the tiniest possible amounts of a substance which can exist and yet be that substance. Thus, in Volta's cell the zinc plate is composed of zinc molecules, the copper plate of copper molecules, and the diluted acid is a mixture of water molecules and acid molecules.

(b) *Molecules are composed of atoms.* Molecules, and therefore substances, are different from one another because they contain different atoms. Thus, a molecule of sulphuric acid contains

two atoms of hydrogen, one atom of sulphur, and four atoms of oxygen. All the molecules of sulphuric acid are alike in this respect.

(c) *Atoms are composed of electrons.* Atoms are different


FOUR ATOMS OF HYDROGEN EACH ATOM CONTAINING(1) ONE REVOLVING ELECTRON
ONE ATOM OF NITROGEN CONTAINING -7- REVOLVING ELECTRONS
ONE ATOM OF CHLORINE CONTAINING- 17 REVOLVING- ELECTRONS
ONE MOLECULE OF SAL AMMONIAC
ONE MOLECULE OF ZINC CONSISTING OF ONE ATOM
THIS ATOM CONTAINING 30 REVOLVING ELECTRONS
ONE MOLECULE OF CARBON CONSISTING OF ONE ATOM
THIS ATOM CONTAINING 6 REVOLVING ELECTRONS

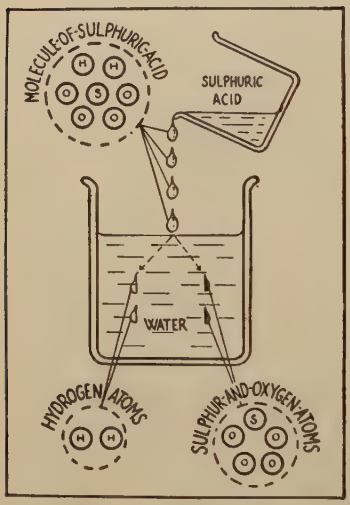
37. What a dry cell is.

from one another chiefly because they contain different numbers of electrons. All electrons are alike. Thus, in the hydrogen atom, there are two electrons, one of them rather stationary and the other revolving around the first, very much as the earth revolves

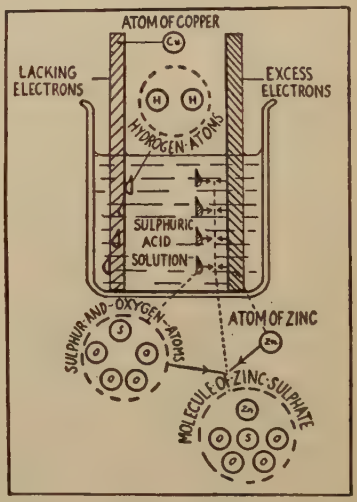
around the sun.* In the oxygen atom there are eight revolving electrons.

(d) *Electrons are bits of electricity.* Thus, matter is really electricity and electricity is matter.

(e) When the acid is diluted with water, *the water molecule*



38. When acid is poured into water.



39. Chemical action in a cell.

separates the hydrogen atoms from the rest of the acid molecule. In this separation, the two hydrogen atoms stay together and the sulphur-oxygen atoms stay together. See figure 38.

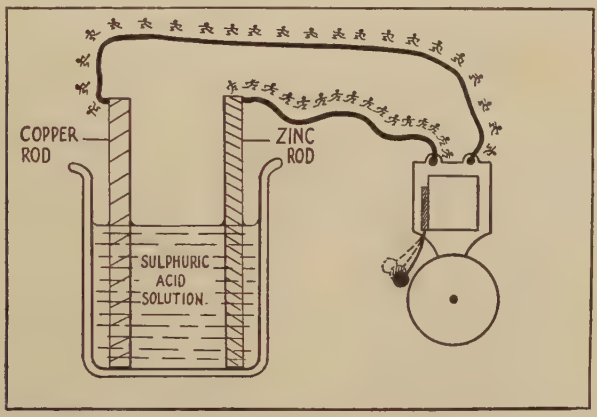
(f) As a result of this separation, *the sulphur-oxygen atoms in each molecule carry away with them two electrons belonging to the hydrogen atoms,* leaving each hydrogen atom with only one electron instead of two.

(g) *The zinc atoms combine with the sulphur-oxygen atoms* to form a new molecule, known as zinc sulphate. See figure 39. The extra electrons which the sulphur-oxygen groups brought with them are delivered to the zinc plate. As this continues, the zinc

*The stationary electron is held fast by two particles known as protons, and there always are as many protons in an atom as there are electrons. It is not necessary at this stage, to consider the protons.

plate accumulates a great many electrons in excess of the number it should normally have.

(h) *The hydrogen atoms,* in order to get back the electrons of which they were robbed, surround the copper plate and *extract from it the electrons* which they need to bring them back to the normal condition. Thus, in becoming normal hydrogen atoms, they cause the copper plate to lack electrons.



40. Electrons move from where they are in excess to where they are lacking.

(i) *Electrons will move from a place where they are gathered in excess to one where there is a lack of electrons.* If now we provide a path (in the form of a wire) from the zinc plate, where there is an excess of electrons, to the copper plate, where they are lacking, the electrons will move in this path from the zinc to the copper.

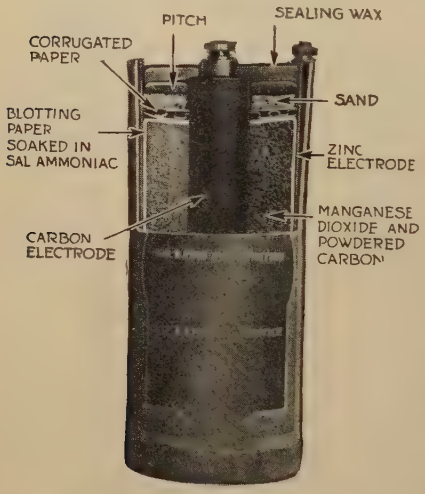
(j) *An electric current is a movement of electrons.* The movement of electrons from the zinc to the copper is an electric current. See figure 40. If part of the path is a coil of wire, the moving electrons will, of course, make this coil an electromagnet.

3. The dry cell produces an electric current

The dry cell, or battery as we sometimes call it (though this is wrong), resembles Volta's simple cell.

If you have an old, used up cell, break it open in order to see

of what it is made. First crack the layer of tar at the top by striking it with a hammer. See figure 41. Then you will find a layer of soggy paper. Pry this up with a knife. Running down through the centre of the cell is a carbon rod. Grip this with a pair of pliers and twist it out carefully. Save this rod for an experiment. You now have left a zinc cup and a mass of black and grayish powder.



41. What you will find in a dry cell.

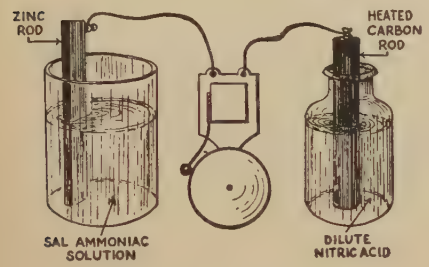
If we compare these parts with Volta's cell we find that there is a zinc plate in both cells, that a carbon rod has been substituted for the copper plate, and that a moist paste of sal ammoniac plays the part of the acid. The black powder is introduced to remove the hydrogen bubbles which form on the carbon rod. The action in the dry cell is exactly as described for Volta's cell. Here, too, the zinc accumulates a great many electrons in excess which will move to the carbon, where they are lacking, when a wire is connected leading from the zinc to the carbon.

If you like to experiment by yourself, you should try to make your own cell. Dissolve about one-fifth of a tumbler of sal ammoniac in a tumber of water. (You can buy sal ammoniac in any drug store.) Using the carbon rod from an old dry cell, place it in the solution, together with a strip of zinc. (Buy the zinc in a hardware shop.) Twist the bare end of a copper wire around the zinc strip and the end of another copper wire around the carbon rod. Connect the loose ends of the wires with a bell. If the bell does not ring, it is probably because the hydrogen bubbles around the carbon rod break the circuit. Remove the rod, heat it in a flame and wash it with acid. (Dilute nitric acid

works very well.) See figure 42. Insert the rod thus treated back into the solution. The bell will now ring for some time.

4. The dry cell is preferable to the wet cell (Volta's cell) as a source of current

It is only in the last fifteen years that the dry cell has become popular. Formerly wet cells of all kinds were in common use.



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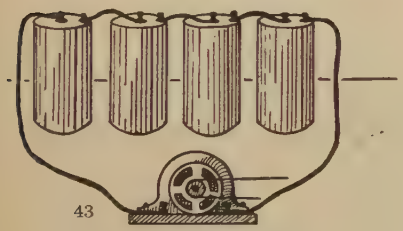

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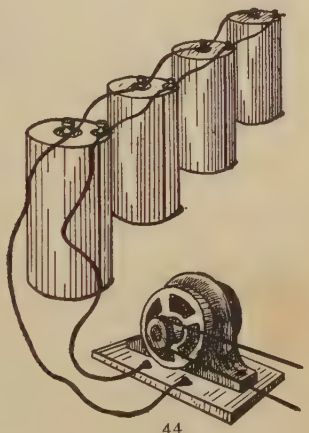


44

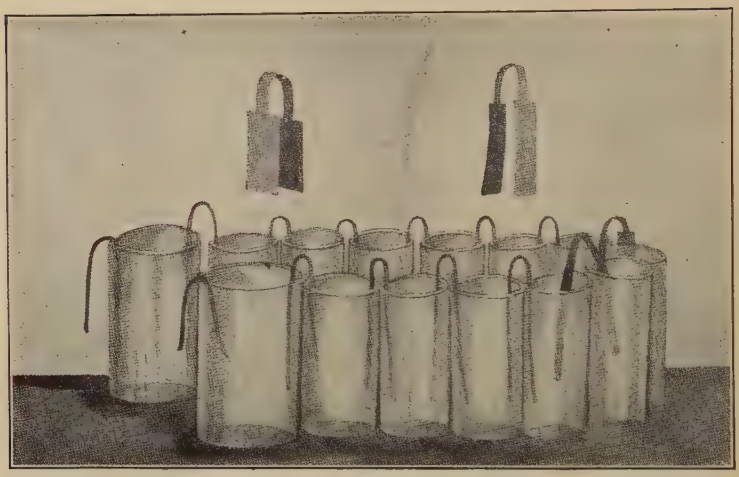
42. After washing in acid, transfer carbon to battery jar.
43. Dry cells connected in series.
44. Dry cells connected in parallel.

The dry cell is very much more convenient to carry about, there is no liquid to spill, and it does not deteriorate rapidly when not in use.

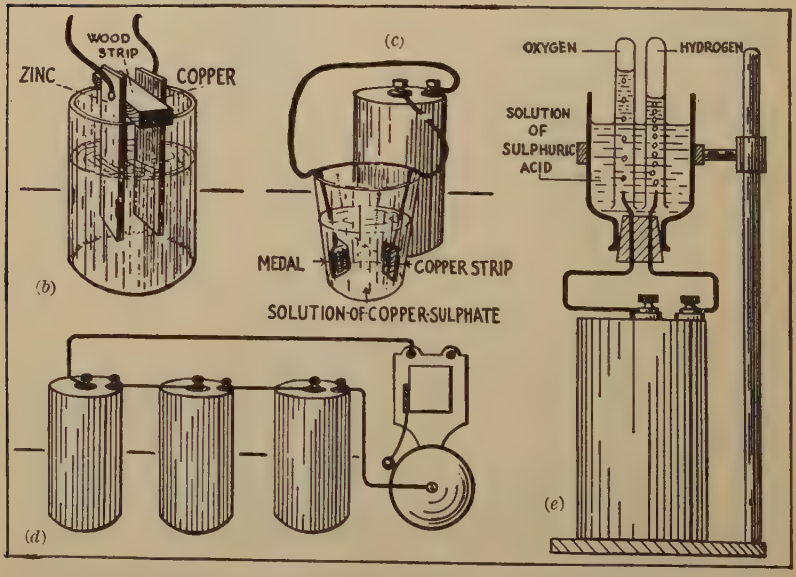
5. Batteries are cells so connected as to give more power and to last longer

Each cell has two terminals—a carbon terminal and a zinc terminal. In connecting several cells there are two ways in which the terminals may be connected.

(a) Each zinc terminal of one cell may be connected with the



(*a*) This is known as "Volta's Crown of Cups." Is it a series or parallel circuit?



(*b*) A good way to keep electrodes apart. Try it out in your homemade cell. (*c*) How to electroplate your medal. (*d*) What's wrong with this picture? (*e*) How to break up water into hydrogen and oxygen.

45. PROBLEM PICTURES.

carbon terminal of the next cell, leaving one zinc terminal and one carbon terminal free for connection with the device you wish to operate with electricity. Such a connection is known as a *series* connection. See figure 43. When cells are connected in this way you add the electrical pressure of one cell to the pressure of the others and get a flow of electrons at high pressure (voltage); in a radio B-battery 30 cells are connected in series to give a pressure of 45 volts.

(b) All the zinc terminals may be connected and all the carbon terminals may be connected, the device being operated by wires coming from any zinc terminal and any carbon terminal. Such a connection is known as a *parallel* connection. Connected in this way cells last longer. See figure 44.

HOW MUCH DO I REMEMBER?

A

Below are two lists. Each item in the first list is closely connected with "one" particular item in the second. Can you pick out "the one" in each case? Write your answers on a sheet of paper so as not to mar the book.

A. Franklin.
B. Galvani.
C. Volta.
D. A unit of electrical measurement.
E. Molecule.
F. Hydrogen atom.
G. Electric current.
H. Zinc atom.
I. Carbon rod.
J. Electron.
K. Parallel connection.
L. Series connection.

1. A bit of electricity.
2. Volt.
3. Part of an acid molecule.
4. The dry cell.
5. Lightning.
6. Zinc terminals connected together.
7. Part of a dry cell.
8. The tiniest amount of a substance which can exist and still be that substance.
9. The copper-zinc cell.
10. Frog's legs experiment.
11. A movement of electrons.
12. The smallest possible piece of zinc.
13. Part of a zinc molecule.
14. Arrangement for getting greater electrical pressure.
15. Thirty cells connected together.

B

Fill the blank spaces with the proper words. Write your answers on a sheet of paper so as not to mar the book.

1. Franklin showed that lightning was .....
2. Volta is the author of the idea that electricity can be made to flow by ..... action.
3. The parts of the simple cell are (1) ....., (2) ....., and (3) .....
4. The action in a cell is explained by the ..... Theory.
5. All substances are composed of .....
6. ..... are composed of atoms.
7. Atoms are composed of .....
8. The ..... plate accumulates electrons in excess of its normal number.
9. Electrons will flow from where there is an ..... to where there is a ..... of electrons.
10. Electrons flow from the ..... plate to the ..... plate when the plates are connected with a wire.
11. The black powder in a dry cell is introduced for the purpose of .....
12. The essential parts of the dry cell are (1) ....., (2) ..... and (3) .....
13. Dry cells are preferable to wet cells because .....
14. If the zinc terminal of one cell is connected with the carbon of another, the two cells are connected in .....
15. If an electromagnet is to be as strong as possible when operated by two cells, these must be connected in .....

THINGS TO THINK ABOUT AND FIND OUT ABOUT

1. If a dry cell is cut in half cross-wise, can the parts be used at all to supply current?
2. What is the voltage of a dry cell?
3. What factors will cause a cell to "go bad"?
4. What would be the voltage of six cells connected in series? Six in parallel?
5. When are cells connected in series? In parallel?
6. Have you ever heard the expression, "He was galvanized into action"? What does that mean?
7. Is a dry cell really dry? Explain.
8. John punches holes in the sides of a used-up cell and immerses it in water for a while. By this process he makes them usable for a little while longer. Explain why.
9. How would you test a cell to know whether you are buying a good one or not?

10. Find out how the cells in a flashlight light the bulb. Make a diagram to show this.
11. What are the three most important uses of cells?
12. How many dry cells would be needed to light brightly the ordinary house electric lamp?
13. The following are terms and names one often hears or reads about in connection with cells. Find out what they mean and what they are.
    (a) electrodes
    (b) electrolyte
    (c) Leclanche Cell
    (d) Gravity Cell
    (e) Bunsen Cell
    (f) Voltaic Pile
14. Find out what you can about the torpedo fish and the electric eel.
15. Find out how radio B-batteries and C-batteries are constructed. Make diagrams to show their construction.

THINGS TO DO AND MAKE

(The letters and page numbers refer to the books listed on page 18.)

1. An electric cell from a lemon.
   Book D, page 171.
2. How to make a dry cell, using tinfoil.
   Book F, page 319.
3. Various ways of making electric cells.
   Book C, page 53; Book E, page 69; Book G, page 9; Book H, page 330; Book I, page 135; Book J, pages 5, 17, 19 and 21.
4. A floating battery—a battery and a compass in one.
   Book A, page 135.
5. How to make a dry cell which can be renewed.
   Book F, page 300.
6. An easy way in which to revive a used-up dry cell.
   Book C, page 64; Book F, pages 23 and 107.
7. How to generate electricity with heat.
   Book C, page 354; Book D, page 169; Book H, page 230.
8. Experiments and stunts with frictional electricity.
   Book A, page 85; Book B, pages 313 to 322; Book C, page 21; Book D, page 165; Book E, page 27; Book G, page 118; Book H, page 312.
9. Electrifying soap bubbles.
   Book B, page 203.
10. How to make an electrophorus. The name sounds difficult but it is easy to make and lots of fun.
    Book C, page 27; Book D, page 184; Book E, page 35; Book F, page 328.
11. How to make a frictional electric machine.
    Book A, page 111; Book C, page 30; Book E, page 42; Book G, page 205.
12. Experimenting with your electric machine.
    Book C, page 49.

CHAPTER V

THE STORAGE CELL

Living in a large city has many advantages. After we become accustomed to crowds and to noise most of us enjoy the many fine things to be had only in large cities. And yet, lurking in every great convenience of city life there is some great danger.

Let us think of the subway station at Times Square during the homeward rush hour. Hundreds of thousands of men and women are jammed against each other and against subway doors—so that they can hardly breathe. Subway guards and even steel railings seem hardly able to keep back the crowds which threaten to overflow the platforms and push people down to the deadly third-rail. Should the lights go out at such a moment, a terrible catastrophe would result. Left in pitch darkness, men, women and children might go wild with excitement and fear. Many would be trampled to death, many would be electrocuted, thousands would be seriously injured.

Now, what safeguard is there against such an emergency? Surely the power plants which supply electricity are not infallible. True, they very seldom fail; but in our homes, lights do occasionally go out.

Engineers who are given the responsibility of this problem have planned in many ways to insure a constant supply of electricity for illuminating the subways. Though power plants are extremely reliable, an independent source of current-supply has been provided. This independent source is a series of *storage batteries*. Should anything happen to the main supply, the storage batteries would automatically assume the burden.

There are many other occasions in modern life when we must rely on batteries for the convenient electrical force to which we have become accustomed. The automobile, for example, has become almost a necessity, and there is no automobile to-day with-

out its storage battery. Radio receiving sets, until recently, depended entirely on storage battery current.

In many instances storage cells are replacing the dry cell. Dry cells do not supply so even a flow of current. They are costly, and when used up must be thrown away. Storage cells last for a very long time in comparison and in the long run are more economical. The evenness of their current flow is what makes them particularly valuable in radio receiving sets.

The storage cell was not invented by one man. Many men in all parts of the world contributed to its development. It all started with Volta; for when he showed that a chemical action resulted in a flow of electricity, the question naturally was asked whether a flow of electricity would produce a chemical change in a solution. This question was answered affirmatively when two men, Nicholson and Carlisle, decomposed the water molecule by sending an electric current through it. A few years later, Sir Humphrey Davy isolated two chemical elements with the aid of an electric current. To-day more than half of the world's copper is refined by means of the flow of electric current. With the electric current we force the nitrogen and the oxygen in the air to combine and from this combination get fertilizers, explosives, perfumes, medicines, drugs, and dyes.

Bleaching solutions, silver plated articles, plates for printing, and thousands of other useful products have resulted from the chemical action of an electric current.

Shortly after Nicholson and Carlisle broke up water into its components by means of an electric current, some one noticed that on disconnecting the current supply, there was a tendency for a current to flow out from the solution. It was as if the electric current had caused certain chemical changes which would be able later to cause a current to flow in the opposite direction. As is usual among men of science, once they have discovered an idea, they try it out on all kinds of substances and under all conditions. It was soon found that if a solution of sulphuric acid is used with plates of lead immersed in it, the flow of electricity through such a cell produces considerable chemical change on the plates and in the solution. Furthermore, these changes are of such a nature that the cell acts as an ordinary simple cell and

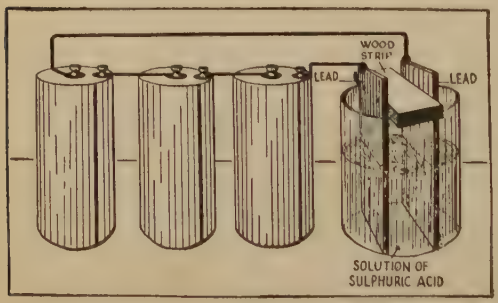
can send out a flow of electricity. Out of this grew the modern storage cell.

1. A storage cell resembles a simple cell

If we examine a storage cell we find two lead plates immersed in a solution of acid. See figure 46. The lead plates play the same part in the cell as do the zinc and copper plates in the simple cell. The acid solution corresponds to a similar solution in the simple cell. However, before a current will flow from a storage cell, the cell must first be "charged"; that is, a current of electricity must first be sent through the cell from an outside source.

If you are interested in this subject you should make a storage cell yourself. The materials are cheap and easy to get, although the acid is somewhat dangerous and you will have to learn how to handle it.

First get a glass jar wide enough to hold the lead plates, which should be about four inches square. The plates can be cut from sheet lead. Buy the lead in a plumber's supplies store. After adjusting the plates in the jar so that they stand upright and are far enough apart to be in no danger of touching each other, pour in about 800 cubic centimetres of distilled water. Get the distilled water in any garage. Into this water should now be poured about 200 cubic centimetres of strong sulphuric acid. This must be poured *very slowly* and the solution stirred while pouring. *Under no circumstance should you pour water into sulphuric acid.* When water and sulphuric acid mix a great deal of heat is generated. If you pour water into the acid, this heat will be sufficient to boil the water into steam as soon as it strikes the acid. The steam will spatter acid on your clothing and perhaps on your face. *Don't try it!* However, if you carefully pour the

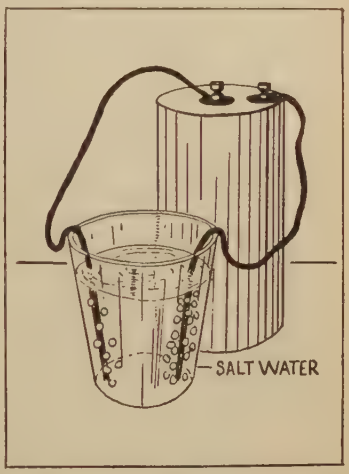


46. Charging an easily made storage cell.

acid into water, there is enough water present to absorb the heat generated and if you pour slowly the water will get warm gradually.

Whatever measure you use, be sure to have four times as much water as acid. In some garages you can buy this acid already mixed in proper proportion. Drug stores will not sell you acid; so don't try to get it that way. Speak to your teacher about getting and using sulphuric acid.

When the plates and solution of acid are in the jar, connect wires from two or three dry cells (connected in series) with the lead plates. See figure 46. After ten minutes of this "charging" process, disconnect and see if your storage cell will ring a bell. How long will it continue to do so? Try charging for longer periods of time.



47. How to test a current supply.

2. A storage cell is charged by connecting its plates with a source of current

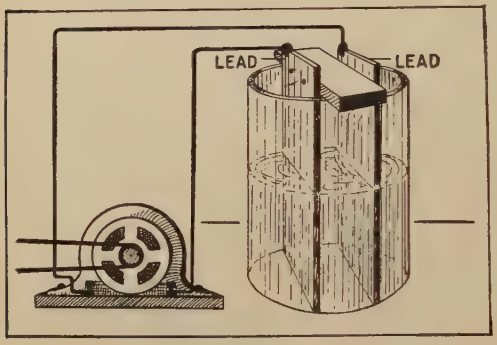
The charging current must flow into the cell, always in one and the same direction. Hence, direct current is the only possible current to use for charging storage batteries. Also, we must find out from which terminal in the storage cell the electrons flow, so as to be able to direct the charging flow into this terminal. Ask your teacher to tell you how to test any current in order to find out in which direction it is flowing.*

3. When charged, the storage cell can cause an electric current to flow

When the plates are connected with wire, after charging, the

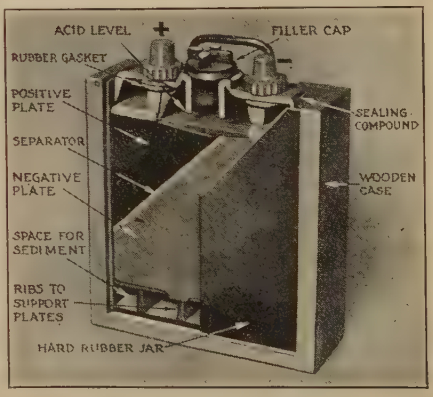
*This test consists of bringing the terminal wires into a little salt water. See figure 47. Bubbles will be given off at both terminals, but from one, twice as many bubbles leave as from the other. The terminal from which most of the bubbles leave is the one out of which the electrons flow. In storage cells this terminal is marked "negative"

current flows out in a direction opposite to that in which the charging current flowed. This flow continues until the plates and the acid return to their condition before charging. During the discharge the storage cell acts exactly like a simple cell. See figure 48.



48. Discharging your storage cell.

The storage batteries used in radio sets and in automobiles are nearly always composed of three storage cells connected in series. Always keep such a battery level so as to avoid spilling the acid. Furthermore, you should keep its temperature even and above the freezing point of water. It must not be overcharged or undercharged; and short-circuits between cells or across the battery should be avoided. Every week or so the top and terminals must be wiped with a dry rag.

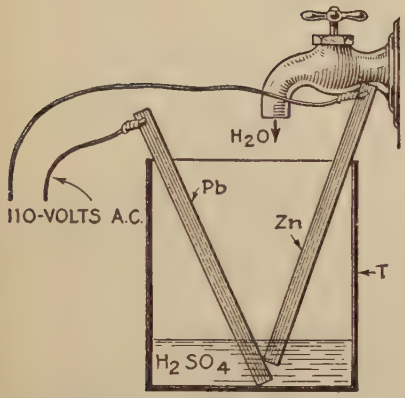


49. Parts of a lead storage cell.

HOW MUCH DO I REMEMBER?

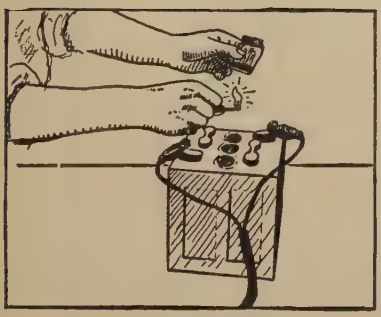
Each of the numbered statements below is incomplete; but with each are listed several possible completions. Select the most correct. Write your answers on a sheet of paper so as not to mar the book.

1. Subway trains carry storage batteries
   (a) to furnish light; (b) to run the motors; (c) to run the motors in an emergency; (d) to furnish light in an emergency.
2. Storage cells are used in
   (a) electric irons; (b) automobiles; (c) radios; (4) vacuum cleaners.

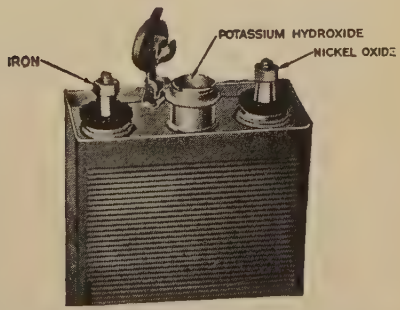


(*a*) There are seven things wrong with this method of charging a storage cell.

(*b*) Explain this method of testing a storage battery.



(*c*) Why is this dangerous?



(*d*) This is a type of storage cell invented by Edison. It is different from the lead cell. Find out how it works.

50. PROBLEM PICTURES.

3. Storage cells are better than dry cells because they
   (a) supply an even flow of current; (b) contain no acid; (c) can be recharged; (d) are so cheap that when they become discharged you can discard them and get new ones.
4. The water molecule was first decomposed by
   (a) Volta; (b) Nicholson and Carlisle; (c) Sir Humphrey Davy.
5. The discovery of the principle that an electric current may produce chemical change resulted in
   (a) Volta's discovery of the simple cell; (b) the development of the storage cell; (c) the development of the dry cell; (d) the discovery of many useful processes where electric cells are not concerned.
6. The storage cell resembles the simple cell because
   (a) both have zinc plates; (b) both have to be "charged"; (c) both consist of two plates immersed in a solution; (d) both produce electricity by chemical change.
7. To make a sulphuric acid solution for a storage cell you must
   (a) pour sulphuric acid slowly into the water; (b) pour sulphuric acid quickly into the water; (c) pour water slowly into the sulphuric acid; (d) pour water quickly into the sulphuric acid.
8. A storage cell is charged by
   (a) adding distilled water; (b) adding more sulphuric acid; (c) connecting its plates with a source of direct current.
9. A storage battery is
   (a) a storage cell; (b) a number of storage cells connected in series; (c) a number of storage cells connected in parallel.

THINGS TO THINK ABOUT AND FIND OUT ABOUT

1. Find out about the arrangement which turns on a small electric light in a subway car at the moment the other lights go out.
2. When would you use dry cells and when storage cells?
3. What is the voltage of one storage cell?
4. How many cells in the common six-volt storage battery?
5. How many volts are furnished by the common automobile storage battery?
6. What may be wrong with a storage battery that fails to give current?
7. What is "stored" in a storage battery?
8. Why do storage batteries lose their "charge" if allowed to stand unused?
9. Find out how to care for a storage battery.
10. Why should only distilled water be used in a storage battery?
11. What is the future for the storage battery in radio receiving sets?
12. Find out about Edison's storage battery. What is its special use and advantage?
13. How do you test the condition of a storage cell?

14. Find out how to use electricity to
    (a) copper-plate a piece of statuary; (b) silver-plate a medal; (c) copper-plate a phonograph record; (d) make an electrotype.
15. What does electrolysis mean? How is water electrolyzed?
16. Reproduce on a sheet of paper the table given below and fill in the blanks.

	STORAGE CELL	DRY CELL
Cost		
Voltage		
Maximum amount of current		
Evenness of current flow		
Length of life		
Necessary care		
Special advantages of one over the other		

THINGS TO DO AND MAKE

(The letters and page numbers refer to the books listed on page 18.)

1. How to make a storage cell.
   Book E, page 79; Book C, page 76; Book F, page 245; Book G, page 175.
2. How to make and charge a simple storage cell.
   Book H, page 337.
3. How to make a battery-charger for your radio A-battery.
   Book F, page 342.
4. How to break up water into hydrogen and oxygen.
   Book D, page 288; Book H, page 31.
5. Explosive soap bubbles. Book A, page 140.

CHAPTER VI

MAGNETIC INDUCTION (FARADAY'S PRINCIPLE)

We do not know whether you performed the experiment with sulphuric acid that we described in the last chapter. We hope you did. We hope, too, that you were careful and that you ruined neither your clothing, the household furniture, nor your body. Perhaps you were frightened by our warnings and never tried it. Perhaps, too, your parents or your teacher advised you not to run the risk. If so, there is no blame to be attached. You were wise in "playing safe." There are men and women in this world, however, who care little for danger, for suffering, or even for life, so long as they can discover new ideas, new facts, new countries, new animals, and new experiences. We call them heroes, pioneers, and great benefactors. Their names go down in history and they are honored for centuries after they have lived.

Columbus was such a man. Daniel Boone was another. Cyrus Field, about whom we learned in Chapter III, will always be remembered for his courage and patience in pursuit of an ideal. In our present day, we admire and respect Thomas Edison and Charles Lindbergh. We think of Commander Byrd in the cold and dreary Antarctic, working his way to the South Pole, charting a country uninhabited by man and shutting himself away from all comforts of life for two years. Byrd too is a hero, ready to sacrifice everything for the sake of human knowledge.

In this chapter we are to study a principle of science discovered by one of the world's greatest pioneers. His discovery, simple though it was, has changed life all over the world. Indeed, the effects of the discovery are still developing. Every day sees a new application of it—a new invention based on his famous experiment.

Michael Faraday was his name—and he was an English scientist, born in 1791. Experimenting was his great hobby. Day after day, year after year he would retire to his laboratory pursuing nature's secrets. Personal safety did not count for very much when he was experimenting. He had many narrow escapes. In one experiment, an explosion shattered a glass flask, sending fragments into his hands, face, and eyes. In fifty years of scientific research Faraday performed 16,041 experiments,—practically one a day. The reason we are certain of the number is that he kept a notebook—a Science Notebook—in which he wrote up every experiment he performed.

This habit of Faraday's, of keeping accurate notes, stood him in good stead. In fact it gave him his start in science. Until he was twenty-one, Faraday was a bookbinder. Though he was skilled in his trade his chief interest lay elsewhere. One day a friend of his presented him with tickets to a series of lectures to be given by the great scientist, Sir Humphrey Davy. Faraday attended the lectures, taking detailed notes of all he saw and heard. When the series was over he wrote up his notebook and sent it to Davy. Davy was astonished and pleased. Not long after this a vacancy occurred in the laboratory. Faraday was given the place and he became Davy's bottle washer. To be in a science laboratory near an experimenter like Davy was an opportunity; and Faraday took full advantage of it. The young man's genius was at once apparent to all who saw him and his achievements were hailed by the whole world. Talking about himself, Sir Humphrey Davy once said, "My greatest discovery was Michael Faraday."

Now, of the many thousands of experiments which Faraday performed, one stands out above all the rest. This was an experiment which taught the world a better way of making electrons flow. Just as Galvani and Volta improved on the ancient Greek method of rubbing things together, Faraday improved on Volta's method of getting electricity through chemical action. Faraday employed magnets and coils of wire.

Useful as batteries are and convenient as they may be for some purposes, their current flow is very limited. For some of their experiments Davy and Faraday had to connect together

2,000 cells. Faraday felt that some way could be found of causing large currents to flow.

In previous chapters we learned that several important discoveries were the results of accidents. Not so in the case of Faraday's great discovery. When Oersted showed that electricity flowing through a wire would move a magnet near it, Faraday

51. Some think Faraday is entitled to royalties from every advertiser shown in this picture. What do you think?

immediately asked, "What will happen in the wire if we move a magnet near it?" To ask was to try. For nine years he tried. Finally he saw. *Moving a magnet near a coil of wire or a coil of wire near a magnet causes a movement of electrons in the coil.*

This discovery, as you read the above statement of it, does not seem to be startling. Nevertheless it brought the dawn of a new age—the Age of Electricity. It made possible the dynamo, the telephone, the electric motor, the electric light, the automobile, the X-Ray, wireless, radio, the motion picture, and television.

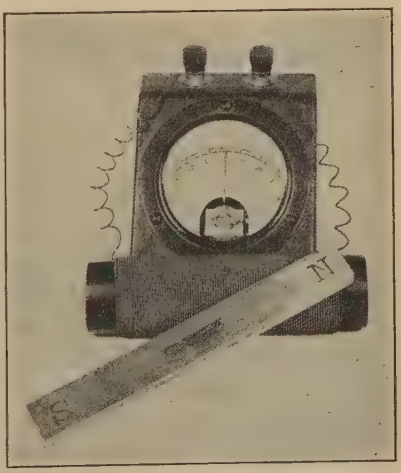
If Faraday had taken out a patent for his basic discovery, his descendants to-day would be the wealthiest men in the world.

Every automobile owner would be paying Faraday something for the use of his idea in the ignition system. All of us who use the subway are taking advantage of his discovery, and we might be asked to pay. Whenever we snap on an electric light or go to the theatre, Faraday might ask us to pay him for inventing the dynamo. The telephone company and the broadcasters would all have to pay a tax to Faraday; for all of them depend on the operation of his great principle. During his life Faraday never earned more than $500 a year. See figure 51.

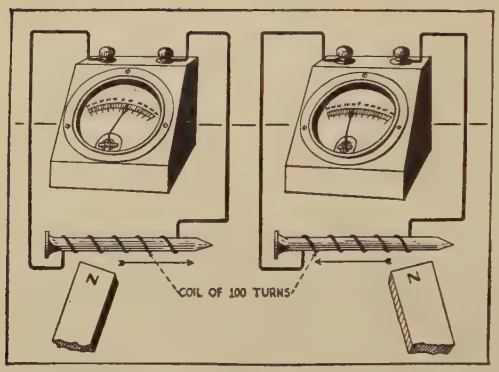
It is amusing sometimes to exercise our imagination. Let us suppose then, that Faraday had never lived, or that his researches had never been made, and that no other man had come to teach the world how magnets could make electricity flow—what sort of world would we be living in? How would our own city change? Try to write down all that might happen to our skyscrapers, our subways, our modes of communication, and our recreations.

1. Moving a magnet near a coil of wire causes an electric current to flow in the coil

In the illustration, figure 52, you see a coil of wire connected with an instrument which can measure a very small flow of electricity. Any movement of the pointer over the dial shows that electrons are moving through the instrument. As you bring a bar magnet near this coil, the pointer moves to the right. As you stop moving the magnet, the pointer stops moving to the right and returns to its former position. Now move the magnet to the left. While the magnet is moving, the pointer again moves, this time to the left; and as the magnet stops, the pointer



52. Moving a magnet in the presence of a coil.



53. Changing the direction of motion changes the direction of the induced current flow.

returns to the middle position. Let us call the current flowing in the coil and through the instrument an *induced current.* As it sweeps by the coil, the magnet with its accompanying magnetic field *induces* the electrons in the coil to flow. Take note that three things are necessary to induce a current: a *magnetic field,* a *coil of wire,* and *motion.*

2. Moving a coil of wire near a magnet causes an electric current to flow in the coil

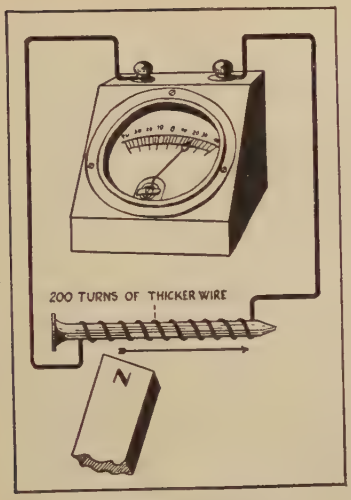
You can repeat the same experiment described above and in figure 52. This time, however, move the coil and let the magnet lie on the table. The same results are observed. It doesn't matter whether the coil or the magnet moves. Let either one be moved and a current is induced in the coil.

3. The strength of the induced current depends upon the strength of the magnet, the number of turns of wire in the coil, and the speed of the motion

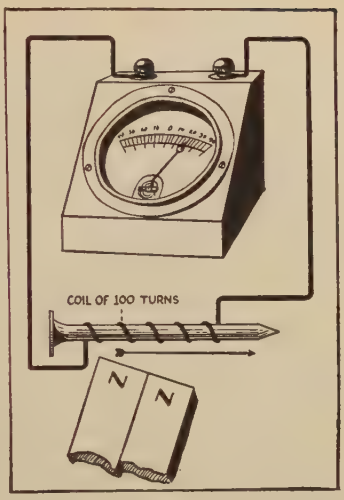
Repeat Faraday's experiment. This time note how far the pointer swings when you sweep a magnet across the coil with a certain speed. Now put two magnets together with their N-ends touching and sweep them across the coil with the same speed as before. You will note that a stronger current is induced, since the pointer swings over farther. See figure 55.

Replace the coil with another that has more turns of thicker wire. See whether the same amount of motion will now induce a stronger flow of current in the coil. See figure 54.

The faster the motion of the magnet the stronger is the flow of



54. Strength of induced flow depends on size of coil.



55. Strength of induced flow depends on strength of moving magnet.

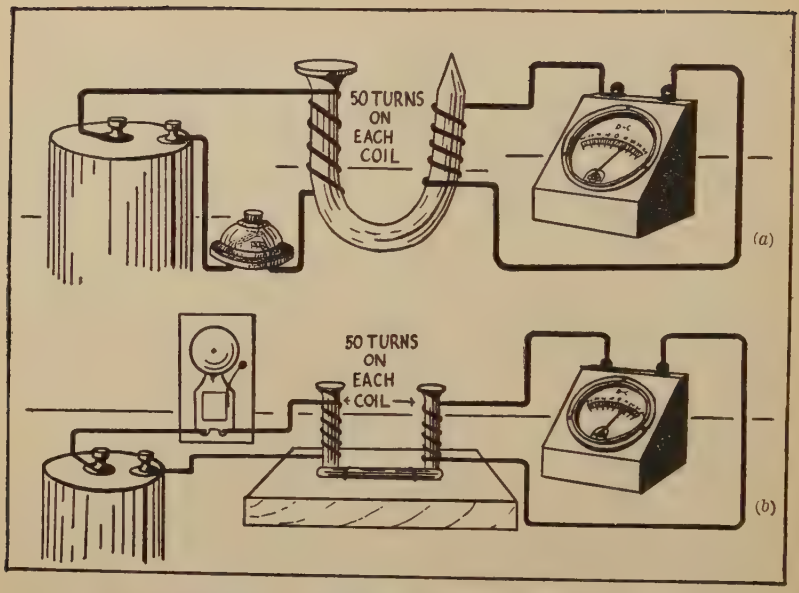
induced current. Try it. If it is the coil which is being moved, again the speed of motion determines the strength of the induced current.

It is very important for us to note here how the induced current keeps pace with the motion. See figure 53. If the motion is regular the induced current is steady in its flow.

On the other hand, a jerky movement of the magnet or the coil will cause a jerky movement of the pointer, indicating an irregular or fluctuating current in the coil.

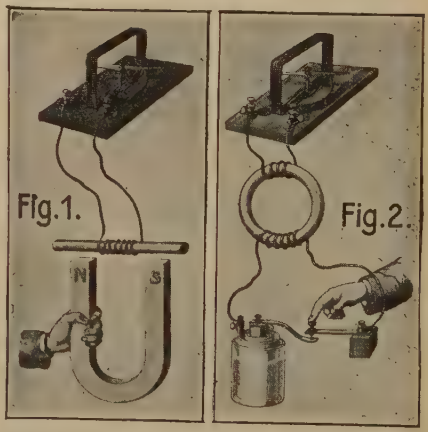
4. The principle of induced current is applied in the construction and action of many important electrical machines

The rest of this section of the book is devoted to an explanation of how Faraday's Principle of Induction is applied to many modern electrical devices. We shall study the dynamo, the induction coil, the transformer, the telephone, the motor, and radio, all of which, as we have already told you, are applications of Faraday's Principle.



(*a*) Induced current. Use a push button as "make and break."
(*b*) Induced current. Use bell vibrator as "make and break."

(*c*) Joseph Henry once performed this experiment. Did he discover the principle of induction?



(*d*) Use a compass needle to show induction.

56. PROBLEM PICTURES.

HOW MUCH DO I REMEMBER?

Electricity may be produced
(a) *by rubbing things together;*
(b) *by chemical action;*
(c) *by moving magnets and coils.*

1. Which of the above methods was known by the ancient Greeks?
2. Which was developed by Galvani and Volta?
3. Which was discovered by Faraday?
4. Which is the best method for most purposes?
5. By which can large currents be made to flow?
6. By which is electricity for lighting your home produced?
7. By which is electricity for charging storage batteries produced?
8. Which method is similar to the production of lightning?

Moving a magnet near a coil of wire or a coil of wire near a magnet causes a movement of electrons in the coil.

1. Say in a different way "a movement of electrons."
2. Name some things which the discovery of this principle made possible.
3. Who discovered this principle?
4. What do we call a current produced in this way?
5. What happens to the current when the direction in which the coil moves is changed?
6. What difference is there in the induced current if you use a stronger magnet?
7. If you use a faster motion?
8. If you use a coil with more turns?
9. If you use a jerky movement?
10. Can an electromagnet be used in place of a bar magnet?

THINGS TO THINK ABOUT AND FIND OUT ABOUT

1. From what you know about prefixes, roots and suffixes, explain what the word "induction" must mean.
2. Make a list of all the electrical devices you know which use induced currents.
3. What is the rule for determining the direction of a current induced in a coil?
4. What is the earth-inductor compass and how does it work?
5. Find out what the letters E. M. F. stand for in the science of electricity.
6. Why is Faraday considered the greatest experimenter of the nineteenth century?
7. What electrical unit of measurement was named after Faraday?

8. If you spin a coil of wire fast enough, holding it in a certain direction, you can light a lamp with the electricity generated in the coil. Can you find an explanation for this?
9. Electricity in motion produces magnetism; magnetism in motion produces—what?
10. The following article appeared in the *New York Times* of April 22, 1927:

WOULD TIME GAMES BY ELECTRIC DEVICE

British Scientist at Cornell Recommends Method for Runners at Olympics.

RACERS CARRY MAGNETS

Magnets Weigh but Little and System Insures Accuracy, Says Professor.

ITHACA, April 21.—In giving an account of his new method of timing runners, Prof. Hill explained that wire coils are placed along the track in lanes at specified intervals. Each runner carries a small magnet and as he passes each of the coils with his magnet, an electric current is induced in it. A wire carries the current to a galvanometer. A beam of light is reflected from the galvanometer mirror so that it makes a point of light on photographic paper inside a camera. As it moves, the point of light makes a graph on the paper. The graph of each runner can be read easily so that the runner may be timed to 1-200 of a second. Prof. Hill declared there are many advantages of this over the old fashioned stop-watch method of timing.

After studying the above account answer these questions:

(a) What causes the currents to be set up in the coils?
(b) Explain what a galvanometer is used for and how it works.
(c) What is a graph?
(d) What are the features of this timer which you do not understand?

Request your teacher to explain whatever is not clear to you.

THINGS TO DO AND MAKE

(See the lists of Things to Do and Make at the end of Chapters VII and IX.)

CHAPTER VII

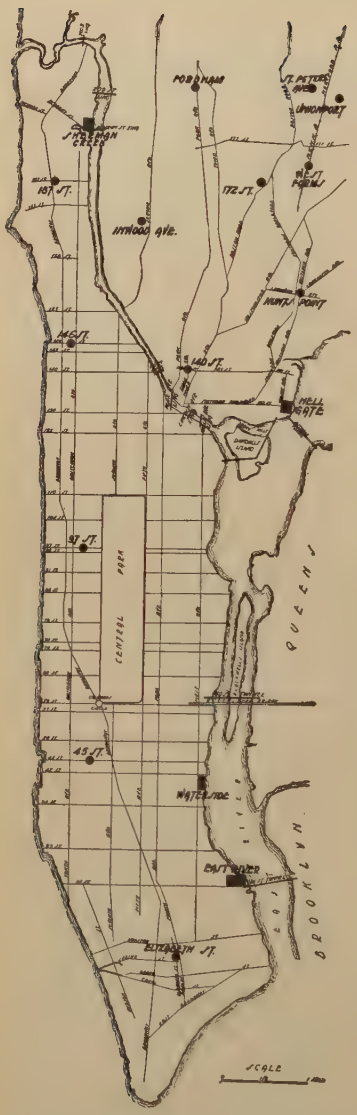
THE DYNAMO

When we think of the heroes in the stories we have read, there is one who excites our envy more than any other. Aladdin and his wonderful lamp! With his lamp Aladdin could do what he wished. He rubbed—and his faithful servant appeared to obey his commands. We envy him because we, too, should like to have such power; and though we do not take the story too seriously, it fascinates us and permits us for a little while to indulge our fancy.

To-day we do not have to dream to find ourselves masters of a wonderful servant. At any moment we, too, can rub a kind of Aladdin's lamp—only we call it "pressing a button." We press —and lo!—a genie appears. Or rather, the electricity flows; and, like the genie, it accomplishes many wonderful things. Occasionally something goes wrong. Our servant does not respond. Like Aladdin's genie, we must treat him with respect or he may cause a good deal of havoc.

Pressing a button, snapping a switch, or turning a knob is an easy thing to do. We do it so often that we forget about the great force which we bring to our service; and some of us are perhaps ignorant of how the force arrives at our elbow so conveniently, how and where it is brought into being, and how it gets to us so quickly.

If we had eyes that could see through plaster and brick, through asphalt pavement and steel, the city in which we live would present a strange spectacle. Looking at a skyscraper we should see a maze of wires running to every nook and corner of the huge structure. In walls, under floors, in ceilings we should see wires and fuses and switches. Following these wires down into the street, we should see them join large cables under the surface. As the cables pass other buildings, they are joined by other networks of wire. At a street corner one main line joins

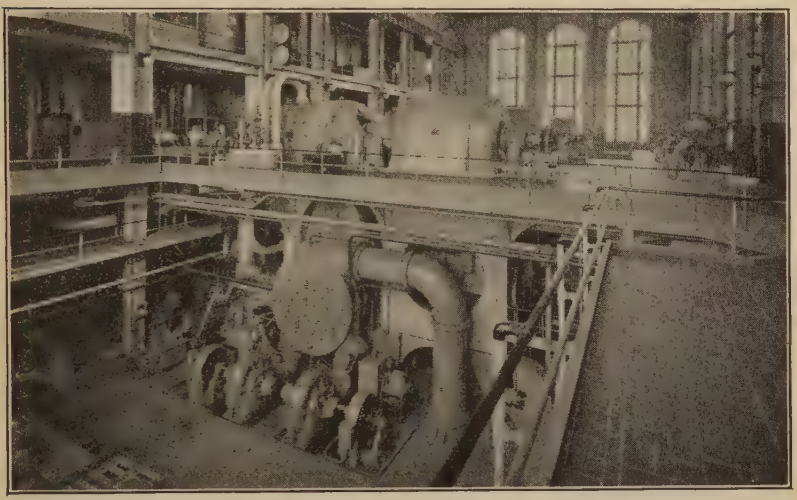


57. Generating stations and substations for New York City. *The United Electric Light and Power Company.*

another. Like branches of a tree they lead into larger and larger avenues until they join the main trunk. Where does the main trunk go? You can follow it for block after block, for miles in fact. One of these main lines will lead you to the East River at 14th Street. Another will take you far up-town to a huge building in the Bronx. They all end in structures that are curiously alike —structures crowned with several tall chimneys and all of them close to a river.

Look at the map shown in figure 57. At the point marked "Hell Gate" we find one of the centres to which our wire cables travel. Each square is a main station and each circle is a substation. It is at the main stations that the electric force is generated. Something happens in these stations which causes electrons to flow out in great numbers so that miles away you can push a button and change darkness into light. You turn a knob and in rush trillions of electrons to operate a radio set. You close a switch and the mighty electric servant speeds to your home in a ten-thousandth part of a second to clean your rugs, toast your bread, cool your room, dry your hair, or freeze water into ice.

Now, what is going on at these generating stations? Let us go in to look around. The first thing that greets our eye is a long room full of furnaces. That explains the chimney and the pro-

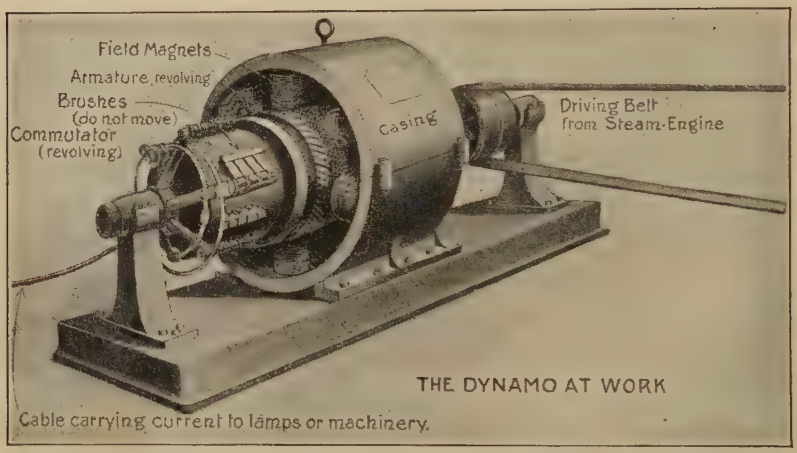


58. A modern generating station.

cession of coal barges that we saw on the river. Evidently vast amounts of coal are being consumed. Why? To boil water, of course; the many pressure gauges we see about hint that there must be steam under great pressure in the boilers above the furnaces. If there is steam about, there must be an engine to be operated. Let us follow the steam pipe. "Here are the steam turbines," says our guide, as we are ushered into a large, well-lighted room where everything is kept spotlessly clean and where the air is filled with a whirring hum of spinning wheels. Each turbine seems to be coupled to another machine which is forced to spin around with it. "These are the largest *dynamos* in the world," announces the guide. "They supply electric light, heat, and power to a large portion of the city of New York. Every twenty-four hours we burn up 2,000 tons of coal. Furthermore, the exhaust steam which we discharge into the river keeps the river several degrees warmer than it would normally be."

If Faraday were alive to-day and could see these modern

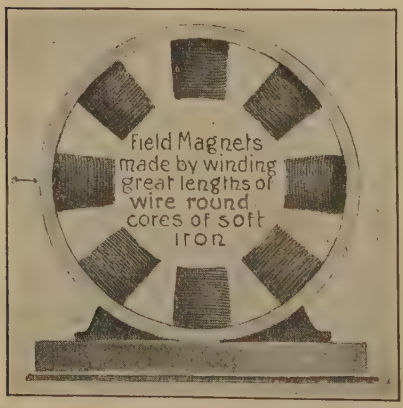
dynamos he would be as astonished as we are to find how complicated a machine his simple experiment has become. The dynamos, as they whir around, are moving coils of wire—moving in



59. Parts of a dynamo. *Copyright F. E. Compton & Co.*

the presence of powerful magnets. On a large scale, they are causing electrons to move, very much as we described it in the preceding chapter.

1. Electric currents may be induced when three essentials are combined. A magnetic field, a coil of wire, and a movement of the coil in the magnetic field

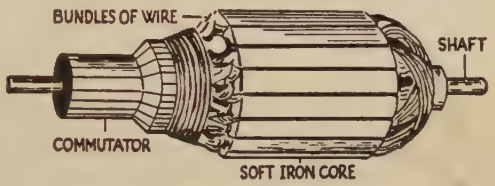


60. *Copyright F. E. Compton & Co.*

In a dynamo these three essentials are combined. The magnetic field is sometimes produced by permanent magnets. If so, we call the device a *magneto*. More frequently, however, the magnetic field is furnished by electromagnets. In dynamos these magnets are known as the *field magnets*.

The moving coil is known as the *armature* and consists of many hundreds of turns, bunched in coils, and wound around a soft iron core.

The motion of the coil or armature may be furnished by hand, by a gasoline engine, by water wheels, by wind-mills, by electric motors, or, as we found in the power stations, by steam turbines.

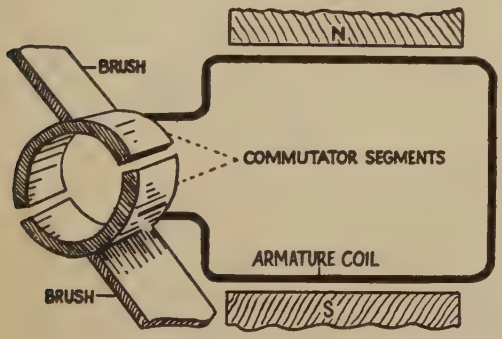


61. Parts of an armature.

To gather the current induced in the moving coils a device known as *commutator and brushes* is provided. The brushes are connected with the power line which feeds the cables leading out into the city. The electrons flow out from one brush and return by the other. See figures 59, 60 and 61.

2. The dynamo produces current by magnetic induction

When the armature coils are rotated in the presence of the field magnets, a flow of electrons is induced in the armature. The ends of each of the coils in the armature are connected with two commutator segments, directly opposite each other. The brushes are in contact with these segments and carry the flow of current to the place where it is being used. As the rotation proceeds, another coil delivers its flow to the brushes through another set of commutator segments. And so on. See figure 62 for commutator segments and brushes.



62. Coil turns with comutator. Brushes and magnets are motionless.

If the connections are such that the flow delivered to the brushes is always in the same direction, the dynamo is called a

direct current generator. In an *alternating current* generator, the commutator is a solid ring instead of being divided into segments. In this type of generator the electrons reverse their direction of flow at regular intervals.

3. The dynamo produces most of our high-power current

By using induced current from dynamos, instead of battery current, we can get for less than one penny an amount of electrical power which would cost us thirty cents or more in dry cells. You can see, therefore, why dynamo current is displacing battery current whenever possible. All over the country great power houses are being built. As we leave the crowded city streets and go for an auto ride in the country, we find tall telegraph poles along every highway. These poles to-day carry more than telegraph wires and telephone wires. They frequently carry power cables that stretch from dynamos in central stations to small farmhouses many miles away. The advantages and convenience of electricity are so great that even the rural districts are developing electric power stations. Where a man lives in a remote country place, so far removed from the power line as to make it too expensive to put up the necessary miles of poles and cable, we often find him installing his own power plant. He builds a little shack and in it he lays a cement platform. To this platform he fastens a gasoline engine and a dynamo. These machines are built in one unit. The engine turns the dynamo and from the brushes of the dynamo he carries a power line to all parts of his house and farm.

The day is not far off when all light, heat, and power will be furnished by induced currents from dynamos. Communication in the United States is already almost entirely electrical, and many railroads are changing from locomotives driven by steam to those driven by electricity.

This increasing use of induced electricity raises a serious problem for our country and for the world. Though there seems to be plenty of copper in the world for the wires and coils needed, and though we can find plenty of iron for magnets, the demand for power to turn the coils in the presence of magnets is rapidly ex-

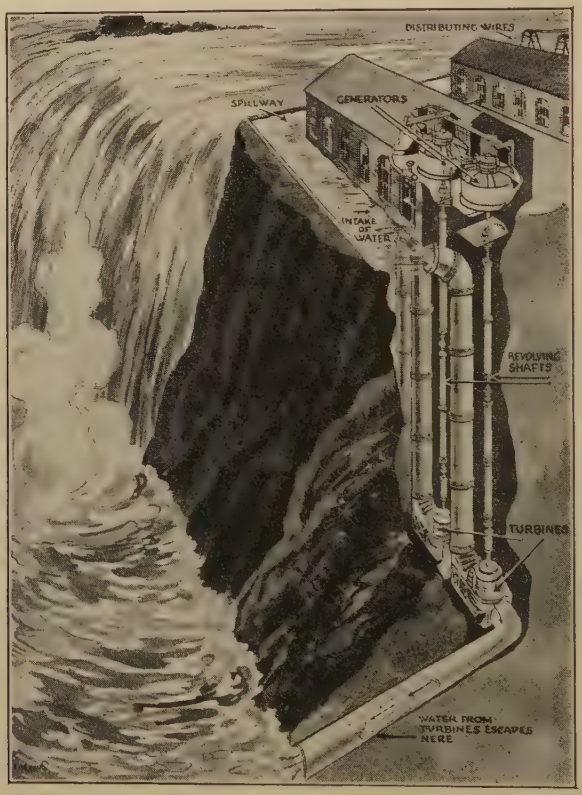
hausting the supply of fuel. Until very recently the chief fuels used in power plants were coal, oil, and gasoline. We are told by geologists that a day will come when there will be no more coal and no more oil. What shall we do then? Now there is one source of power that will never be exhausted while the sun continues to shine. In this country especially we have been letting it go to waste. This great source of energy is *water power.*

63. Modern hydroelectric plant. The dam raises water to a high level.

The heat of the sun evaporates the water from oceans, lakes, and rivers, and the atmosphere is filled with moisture. This moisture condenses and falls as rain and snow; and in time returns once more to streams, rivers, lakes, and oceans. In some parts of the world these rapidly moving water streams can be made to turn wheels. For thousands of years man has been letting waterfalls do useful work in this way. Now we are waking up to the fact that we can use the fall of water in a still better way. Streams and rivers are dammed up until the water level reaches great heights. Then the tremendous water pressure is allowed to

move specially designed wheels fastened directly to the armatures of dynamos. See figures 63 and 64.

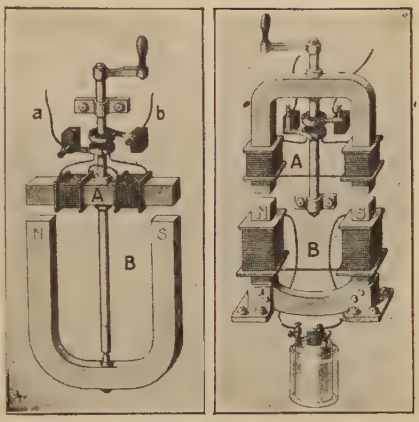
Engineers say that New York State can do away with 80 per cent of its use of coal by taking full advantage of available



64. How the pressure of water is used to turn electric generators.

water power. At Niagara Falls, the fall of water is used to turn dynamos which operate numerous factories and to supply light, heat, and power for hundreds of miles around. During the Great War the United States dammed up parts of the Tennessee River and established a power plant at Muscle Shoals which we hope

will soon be furnishing electricity not only for light, heat, and power, but also for the manufacture of fertilizers, drugs, and other necessities. Another such project in the western part of our country is the great Boulder Dam. Billions of dollars must be spent for this gigantic electrical plant, but when built, it will affect the lives of millions of people, modernize their homes, and change barren deserts into luxuriant gardens.



65. (*a*) An early form of dynamo. What is *A*? *B*? *a*? *b*? Explain how it works.

(*b*) A dynamo used in 1845. How does it differ from the one shown in 65(*a*)? From a modern dynamo?

HOW MUCH DO I REMEMBER?

Is each statement true or false? If false, give your reason. Write your answers on a sheet of paper so as not to mar the book.

1. A network of mains, cables, and wires joins the city house with the generating station.
2. The supply of electricity in most houses comes from dynamos located in these houses.
3. Electric power for large cities is generated at numerous main and substations.
4. Electricity for New York City is produced by water power.
5. The steam turbine is a machine which generates electricity.
6. The magneto is used in the ignition system of an automobile.
7. In large dynamos, the coil or armature is made to move near magnets.
8. The field magnets supply the magnetic field.
9. Field magnets are most often permanent magnets.
10. The wire of the armature is wound around a hard steel core.
11. A direct current will be produced if the commutator is a solid ring.
12. It is advisable under some conditions to use electric power to turn the armature.
13. If the electrons reverse their direction of flow at regular intervals, we have an alternating current.
14. Most of our high power current is produced by dynamos.
15. Dynamo current is displacing battery current because it is cheaper.
16. It is difficult to supply current to country places because of the expense of putting up the cables.

17. It is not possible to build a small dynamo to supply a single farmhouse with electricity.
18. Coal and oil furnish an inexhaustible supply of energy for generating electricity.
19. Throughout the United States full advantage is being taken of available water power for generating electricity.
20. Were it not for the dynamo, water power would be useful only for factories located on the stream in which the water moved.

THINGS TO THINK ABOUT AND FIND OUT ABOUT

1. The dynamo is robbing Niagara Falls of its beauty. Explain why this may be true.
2. What is meant by a "hydroelectric" plant?
3. What is a magneto? How does it differ from a dynamo?
4. What is meant by the term "prime mover"?
5. List six different prime movers employed in the operation of dynamos.
6. Which prime mover is the cheapest? The most expensive? The most common? The most effective?
7. Upon what does strength of dynamo current depend?
8. Find out what the root of the word "dynamo" is and what it means.
9. What do people mean when they say of some one, "He is a human dynamo"?
10. What is a series-wound dynamo? A shunt-wound dynamo? A compound-wound dynamo?
11. How is the speed of a dynamo controlled in the power house?
12. How does an A. C. dynamo differ from a D. C. dynamo?
13. What purpose does the dynamo serve in an automobile?
14. In an electrified railroad, a train running down hill generates considerable electricity. Find out how this is done.
15. It is the energy of the sun which turns our dynamos. Prove this statement.
16. How do ships obtain their supply of electricity?
17. Why is it impossible to operate the dynamos on a submarine when the latter is submerged?

THINGS TO DO AND MAKE

(The letters and page numbers refer to the books listed on page 18.)

1. How to make a dynamo.
   Book C, page 309; Book E, page 180; Book J, page 103.
2. A dynamo from a telephone magneto. Book F, page 233.
3. A hand-power dynamo. Book G, page 121.
4. How to make a magneto generator. Book G, page 104.
5. How to make a reversing switch. Book J, page 116.
6. How to make an alternator. Book J, page 117.
7. How to make caustic soda from table salt. Book H, page 41.
8. How to electroplate your medal. Book C, page 366.

CHAPTER VIII

ELECTRIC CURRENTS OR THE FLOW OF ELECTRICITY

On December 28, 1928, the *New York Times* printed the following news item:

TRAFFIC LIGHTS ON IN UPPER BROADWAY

WHALEN LAUNCHES SYSTEM WHICH CONTROLS VEHICLE FLOW FROM 72ND TO 170TH STREETS

Traffic on Broadway from Seventy-second to 170th Street went under control by traffic lights shortly after noon yesterday. The entire stretch is under unit control and is longer than any previously established unit in the city. Police Commissioner Whalen pulled a switch which put the entire system in operation.

The system will soon be extended . . . giving Broadway continuous control by lights from Bowling Green to 181st Street, a distance of approximately twelve miles. . . .

After seven years of constant toil, two tunnels deep under the Hudson River were brought to within six feet of each other. One of the tunnels started from the Manhattan shore. The other tunnel started from the New Jersey side, meeting the New York tunnel in mid-river. Workmen needed only to remove a few feet of rock and mud to open a continuous channel under the river from New York to New Jersey.

Several miles away, in a warm, clean, comfortable office, a group of men sat around a table. There were present at this gathering engineers who planned the tunnel, prominent business men, and the governors of the two states which the tunnel connected. On the table rested a small electric switch. From this switch ran wires through the building and under the street for miles, till at last they reached the river, where they were carried through the tunnel to a charge of dynamite in the wall of rock separating the tunnels.

After suitable speeches of congratulation the governors pressed

the switch. At the very instant when the circuit was closed the dynamite exploded and the channel under the river was completed.

A power house has just been completed in upper Manhattan. It supplies more than a hundred thousand homes with electricity; yet the whole plant is cared for by about a dozen men. Strangely enough, these dozen men are not overworked. They do not wear overalls, their hands are not dirty, their faces show no traces of exertion of any kind. In fact, most of the time they sit in chairs, watching intently the movement of pointers over dials and the lighting of little lamps. Occasionally they write down something and every now and then they press a button.

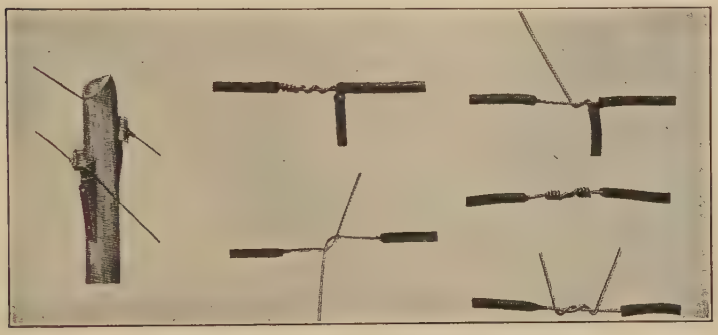
Outside, a clear blue sky suddenly changes to dark and menacing storm clouds. All over the city, people begin to turn on electric lights. An overcast sky makes a great difference to those who live in tall apartment houses. In the power house something must be done quickly. Only one set of dynamos is working. At this time of day this set will meet the demand for electricity very nicely, but if day be suddenly changed to night every available dynamo must be set going.

Before the control man at his desk, a lamp flashes. A device on the roof has reported the condition of the sky. He reaches out and presses a button. Down flows a current to the boiler-room. More coal is dumped into the furnace by mechanical stokers, more water is boiled, more steam is generated, several additional turbines begin to turn their dynamos. In a little while the power plant is ready to meet the sudden demand for more electricity. Knowledge of everything that takes place in the power plant is brought to the control room by small electric currents. The man in control understands the language which the currents speak to him. If he be dissatisfied with things, he presses the proper button and another current will flow to set matters right.

The flow of electricity has become a marvellous thing, though we are growing accustomed to its wonders. The paragraphs above describe only a few of the things which are accomplished every day by the flow of electricity. Yet we are far less aston-

ished at these achievements than the world was when Galvani made his frog's legs jump with electricity.

The next few pages are devoted to a study of how electricity

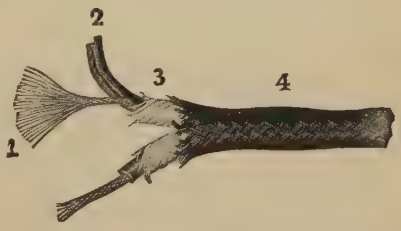


66. How conductors of electricity are spliced.

flows. The experiments you will perform and the facts you will learn will help to explain the world in which you live.

1. Substances through which electrons can move readily are called conductors

Copper, carbon, iron, and most metals are good conductors. Wet earth is also a good conductor. On the other hand, german silver and nichrome (an alloy of nickel and chromium) are poor conductors.



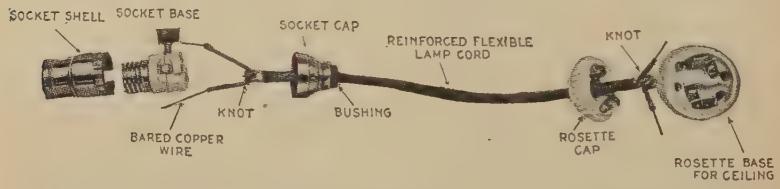
67. Piece of conducting cable for home electrical appliances. Which numbers indicate conductors? Which indicate insulators?

Get a piece of nichrome wire about 12 inches long. Ask your teacher for it. Also, get a piece of copper wire and a piece of iron wire, each about the same length. Connect a dry cell to a flashlight bulb so that there is a 12 inch gap in the circuit. Fill this gap, first with the copper wire, then with the iron wire, and finally with the nichrome wire. Does the bulb light up with the same brilliancy in each case? If you wish to see how good a conductor the earth is, take your cell and bulb

out to the back yard and try to make the earth fill the 12 inch gap in the circuit. Try both dry and wet earth.

2. Substances through which electrons cannot move readily are called insulators

If in the experiment you have just performed you will try to fill the 12 inch gap with cotton, with silk, with rubber, with glass



68. How insulators keep conductors apart in a lamp socket.

and with a piece of friction tape, you will discover that the bulb will not light. Evidently these substances are all insulators. The air, too, must be considered an insulator.

3. Electrons do not begin to move in a conductor unless there is a complete conducting path from and to the source of supply

In all your electrical experiments you have already found that a circuit must be complete. An interesting game to play with your friend is to connect a cell with a bell or a bulb and then make some fault in the circuit. Let your friend try to discover where the break in the conducting path is. See if you can quickly discover the faults which he puts into the circuit.

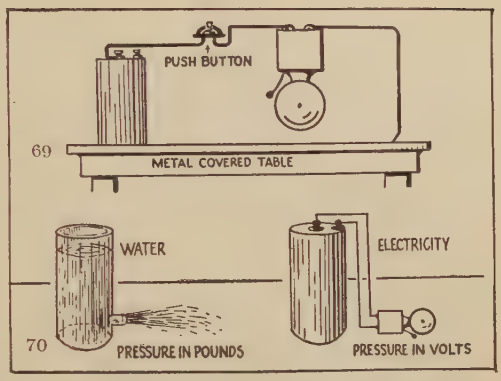
A push button, a key, a switch, and a fuse are all devices with which conducting paths may be completed or broken.

4. The source from which electrons move exerts an electrical pressure which causes them to move.

In a cell the chemical action sets up a pressure from one terminal to the other. In a dynamo, the turning of a coil near a magnet develops a pressure from one brush to the other. Since some pressures are greater than others, scientists have found it necessary to measure these electrical pressures. They do this

with an instrument called a *voltmeter*. A *volt* is a unit of electrical pressure.

For about 75 cents you can buy a voltmeter in a radio shop. It will be a good piece of apparatus to add to your private laboratory. If you can get one, learn how to measure the electrical pressure of cells and batteries with it. A dry cell gives a pressure of about 1½ volts, a storage-battery usually gives about 6 volts, and a large radio B-battery gives about 45 volts. See figure 70.

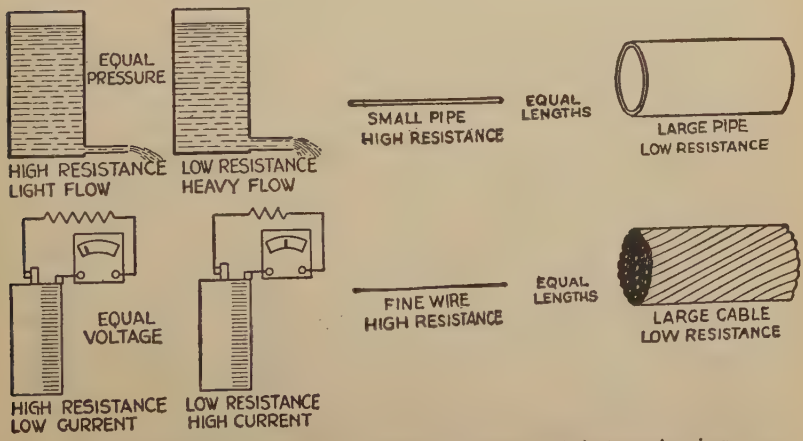


69. A complete conducting path is necessary. Will the bell ring?

70. An electrical pressure causes electrons to move.

5. The obstruction which conductors offer to the movement of electrons is called electrical resistance

The good conductors, such as copper, offer very little resistance to the flow of electricity. Their resistance is low. Iron offers



71. Resisting the movement of water in pipes and of electrons in wires.

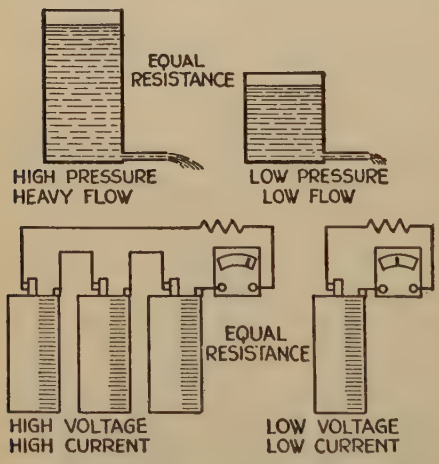
greater resistance and nichrome wire offers still greater resistance. Of course, insulators offer so much resistance that there is practically no flow at all.

It becomes necessary very often to measure the resistance of a conductor. To do this, scientists have adopted a unit of measurement called the *ohm*—named for a great German scientist of that name.

It will be well for you to remember also that the thinner the wire is, the greater its resistance; the longer it is, the greater its resistance; and the hotter it is, the greater its resistance. See figure 71.

6. The rate of electric flow is measured in a unit called the ampere

Here too, science has honored a man by naming a unit after him. Ampere was a great French scientist who lived at the time of Faraday.



72. As with water, so with electricity. The higher the pressure the greater the rate of flow—provided the resistance is the same.

The instrument used to measure the rate of flow is known as an ammeter. You can buy a cheap ammeter in a radio shop. They call it a "battery-tester." With an ammeter and a voltmeter you can test the condition of your batteries.

A brand new dry cell, when connected to an ammeter for an instant, usually shows a flow of about 30 amperes. You will notice we use the words, "for an instant." If you keep a cell or battery connected to an ammeter for even as long as a minute you may ruin the cell or the battery. If you wish to see how much flow it takes to light a bulb, ring a bell, or turn a motor, connect these devices through the ammeter. The pointer in the ammeter will tell you the number of amperes flowing. If the flow is small, there is no harm in keeping the connection for as long as you like. If the flow is great,

you are using up the flow too quickly and your battery will waste away rapidly.

The more resistance you put into your circuit, the less is the ampere-flow. The greater the electrical pressure (the voltage) of your source of supply, the greater is the ampere-flow. See figure 72.

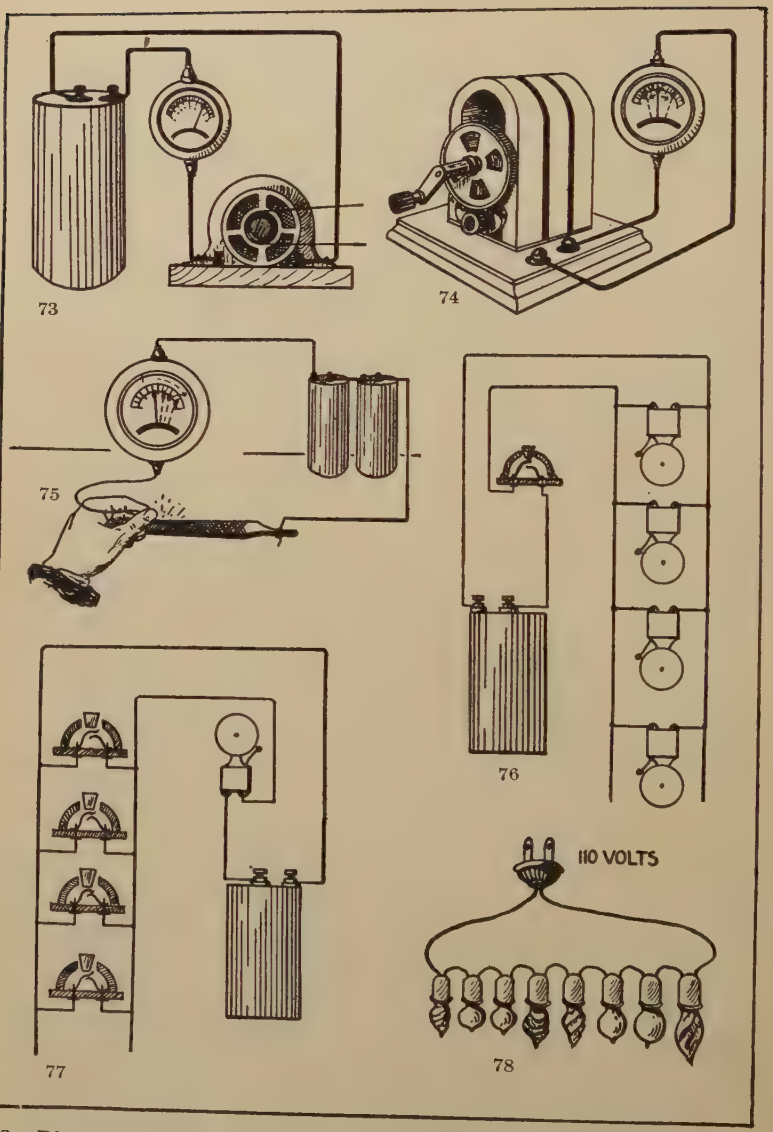
In a complete electrical circuit, the volts always equal the product of the ohms and the amperes.

7. Currents differ in direction of flow, and in strength

When a certain amount of electricity flows continuously in one direction, we call it a *direct current.* Cells, batteries, and direct current generators cause direct currents to flow. If you will connect a battery through an ammeter so that it will turn a motor or ring a bell, you will find that while the motor turns or bell rings, the meter registers a certain amount. This amount stays the same while the device is operating. See figure 73.

When we were studying the dynamo, in the last chapter, we learned that some dynamos did not have commutators and that these were called alternating current generators. Electrons which flow from such dynamos change their direction of flow. As the armature coil moves through half a turn the flow is from one brush to the other. As it completes the turn, the flow reverses its direction. Such current we call *alternating current.*

Another interesting thing about alternating currents is that the strength or rate of flow also changes. If an alternating current generator is connected with an ammeter that has its zero in the middle of the scale, the pointer will be at zero when the dynamo does not turn. As it begins to turn, the pointer begins to move to the right. When the armature has completed one-quarter of a turn the pointer has moved a certain distance to the right. With the next quarter-turn the pointer moves gradually back to zero. The third quarter-turn causes the pointer to move to the left, showing that the direction of flow has changed. The last quarter-turn brings the pointer back to zero. Thus, in the course of one revolution of the armature, the strength of the current has increased to a maximum, decreased to zero, and reversing its direction of flow, it has again increased to a maximum and decreased to zero. See figure 74.



73. Direct current flow.
74. Alternating current flow.
75. Variable current flow.
76. Bells connected in parallel.
77. Push buttons connected in parallel.
78. Christmas tree lamps connected in series.

If the armature speeds around sixty times a second, all the changes we described in the previous paragraph would take place sixty times a second. Each set of changes is called a *cycle;* and such a current would be called a 60-*cycle Alternating Current.* Most of the electricity used in New York City is of the 60-cycle A. C. kind.

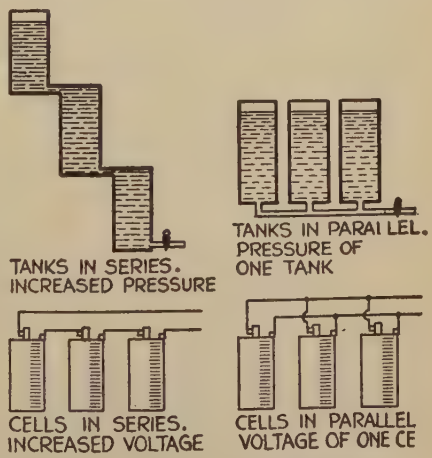
When a current flows always in one direction, but changes its strength or rate of flow, we call it a *variable current.* See figure 75. Variable currents are extremely important, as you will see in later chapters where we study the telephone and radio.

8. Conductors may be connected so that currents will flow through all of them at the same time

Such connections are called parallel connections. In the illustration in figure 76 you can see how to connect one cell and one push button so that they will ring four bells. The current flows through all the bells at the same time. The bells are *in parallel.* In figure 77 you can see how to connect four push buttons so that each one, when pushed, will ring the same bell. Here, the push buttons are in parallel. In trolley cars and in buses such a connection is used to signal the motorman from every seat in the car or bus.

9. Conductors may be connected so that currents will first flow through one and then through the next and so on

Such connections are called *series connections.* In figure 78 you see a set of Christmas tree bulbs connected with a source of current. They are con-



79. As with water, so with electricity. Connection in series gives increased pressure. Connection in parallel gives increased capacity for flow.

nected *in series*. If any bulb burns out, all of them will go out, since there is a break in the conducting path. Why do you suppose Christmas tree bulbs are connected in this way? Did you see the lighted Christmas trees at Times Square and at Madison Square? Are the bulbs in these trees connected in series? Discuss these questions with your teacher.

Sources of current may themselves be connected in series or in parallel. See figure 79.

10. Currents flow through conductors with a speed of 186,000 miles a second

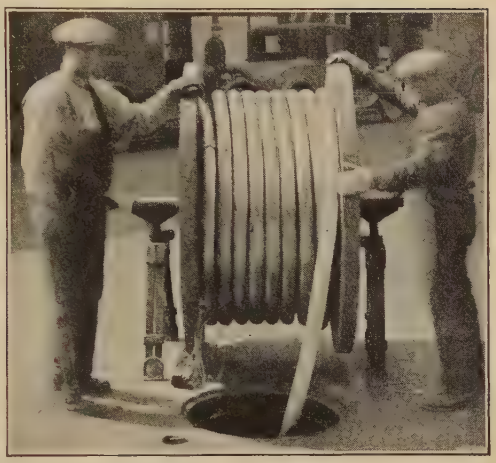
If you had a bulb in San Francisco connected with a cell and switch in New York, the current would have to travel a distance of 3,000 miles from source to bulb when you closed the switch. If it takes one second for electricity to travel 186,000 miles, how long after you closed the switch in New York would the bulb light in San Francisco?

HOW MUCH DO I REMEMBER?

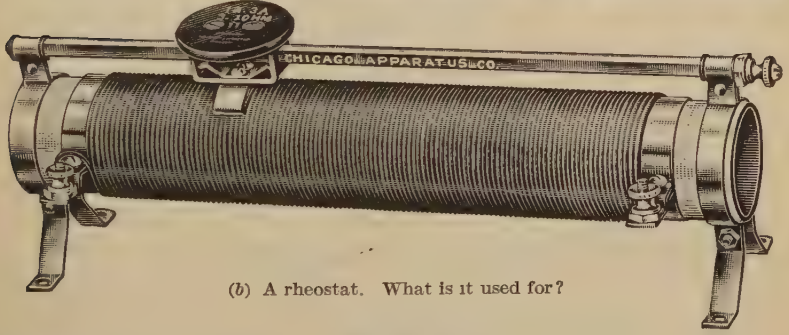
Which statement or statements in List 2 best explains each situation in List 1? Write your answers on a sheet of paper so as not to mar the book.

List 1

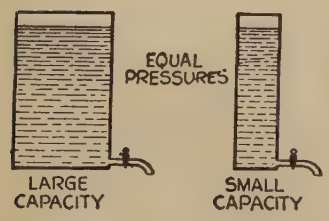
A. By adding an extra cell to the circuit, we increased the flow of current.
B. Electrons move in the wire from the zinc to the carbon terminal.
C. Electric wires are protected with a cover of cotton, silk, and rubber.
D. Commissioner Whalen pushed a switch which turned on all the lights along the avenue.
E. Copper wires are used to make electrical connections.
F. By introducing a strong lamp into the circuit, he decreased the flow of current.
G. One bulb on the Christmas tree burned out and all the bulbs went out.
H. This thin wire offers great resistance to the flow of electrons.
I. Our telephone didn't work. The repair man found that a wire had been cut.
J. The forest ranger always keeps that place moist where his lightning rod is connected to the earth.
K. The man pressed a button and an electric current flowed down to the boiler room.
L. If you add a strong resistance to this circuit, the ammeter reading will be less.
M. The voltage depends on the source of current.
N. Your house current will not be able to run this motor.

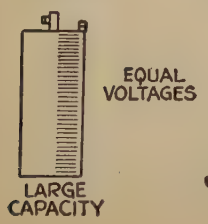


(*a*) You have probably seen such cables being laid. Of what use are they? What do they contain?

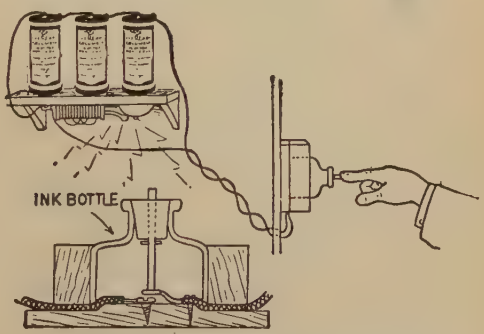


(*b*) A rheostat. What is it used for?





(*c*)



(*d*) Making a push button from a bottle.

(*c*) How does a flashlight cell differ from a dry cell?

80. PROBLEM PICTURES.

O. The current has a pressure of 110 volts. The resistance of the circuit is 10 ohms. An ammeter connected in the circuit will read 11 amperes.
P. Telegraph and power cables are made from thick copper wires.
Q. When the governor pressed the switch, the dynamite, miles away, was almost instantly exploded.
R. He measured the voltage of his storage battery.
S. The telegraph pole supports the cable which is separated from it by glass contrivances.
T. The janitor put in a fuse and the lights went on.
U. By adding an extra cell to the circuit, we increased the voltage.
V. By pushing one button, he rang three bells.
W. When you press the key of the telegraph sender, the current flows through the electromagnet.
X. The current was turned off at the power house. Instantly all lights in the city went out.
Y. The nichrome wire which was used as a resistance had to be wound into a coil.
Z. The fuse in our apartment "blew out." All the other apartments continued to have light.

List 2

1. Conductors permit electrons to flow through easily.
2. Insulators do not permit electrons to flow through easily.
3. There is no flow of current unless there is a complete circuit from and to the source of supply.
4. The source from which electrons move exerts an electrical pressure.
5. The resistance of a wire depends on the material from which it is made, its length, its thickness, and its temperature.
6. The rate of flow of an electric current is greater, if the voltage of the source of supply is greater.
7. The rate of flow of an electric current is greater, if the resistance of the circuit is less.
8. In a complete electrical circuit, the volts always equal the product of the ohms and the amperes.
9. Conductors may be connected so that currents will flow through all of them at the same time.
10. Conductors may be connected so that currents will flow through the first, then the second, then the third and so on.
11. Currents differ in direction of flow and in strength.
12. Currents flow through conductors with a speed of 186,000 miles per second.

THINGS TO THINK ABOUT AND FIND OUT ABOUT

1. In what ways is the flow of electricity in a wire similar to the flow of water in a pipe?

2. How would you wire a lamp so that either one of two switches may turn it on and off? Make a diagram.
3. When a loaded trolley car starts to move there is sometimes a loud report in a device over the motorman's head. What is this device and what does it do?
4. Show in a wiring diagram how subway trains are provided with electric power. Include in your diagram the power house dynamo, the cables, the third-rail and the motors under the cars.
5. Why can a bird sit on a charged trolley wire without being electrocuted?
6. Under what conditions is the air a good conductor of electricity?
7. What is the advantage of "stranded" wire cables over solid wire cables?
8. What causes the flash of electric sparks as an electric train goes round a curve?
9. How do electric signs work?
10. Find out about Ohm's Law? State the law in your own words.
11. Find out about the life and work of Ohm. Of Ampere. Of Volta.
12. "A flash of lightning is a flow of current." Explain this statement.
13. Why is it wise, in an electric storm, to keep away from trees, windows, scissors, wires and knives?
14. Make a list of 10 substances and arrange them in the order of their ability to conduct electric current.

THINGS TO DO AND MAKE

(The letters and page numbers refer to the books listed on page 18.)

1. An electric mouse-killer. Book I, page 113.
2. Using wet silk to indicate the falling of snow.
   Book F, page 201.
3. Using a salt solution to give a rain alarm. Book F, page 321.
4. An alarm for the ice box, mail box and bake oven.
   Book G, page 219.
5. The boxer and the kangaroo. Book B, page 323.
6. How to make a simple rheostat.
   Book C, page 369; Book G, page 192.
7. How to make a reducer for the 110-volt current.
   Book C, page 363.
8. How to make a voltmeter and an ammeter.
   Book C, pages 117 and 126; Book D, page 170; Book E, page 96; Book F, pages 207 and 238; Book G, page 179; Book I, page 116; Book J, pages 149 and 153.
9. How to test for D. C. and A. C. electrical supply.
   Book J, pages 93 and 98.
10. How to test for polarity.
    Book J, page 95.

CHAPTER IX

INDUCTION COIL AND TRANSFORMER

"Blinding streaks of flame sear the laboratory air. A crackle and a sputter like a red-hot boiler dropped in a water tank. Forked lightning writhes, twists, darts from two great balls atop a ten-foot metal cylinder. *Five million volts* are on a rampage —the most stupendous force ever wielded by the hand of man!"*

Dr. Breit and Dr. Ture, electrical engineers, are trying out their new machine. Its purpose is to manufacture electricity—artificial lightning—of a greater voltage than has ever been generated before in a laboratory. When visitors come in to see the machine in operation they stand at a distance. They must, if they value their lives. The scientists themselves are in constant danger, but they know where to stand, what to touch, and how to move. As you watch them among the blue streaks and tongues of flame, they remind you of Jove, that ancient god of the thunderbolt, about whom we read in Greek mythology.

What are they up to? What are they after? Why risk their lives day in and day out? To understand these men and their ambitions we must go back to the year 1896. In that year the power of Niagara Falls was used to turn dynamos and the current generated was used in Buffalo, 22 miles away. Now, you will recall from the last chapter that the longer a wire is the greater is its resistance to the flow of current. Making current push its way to Buffalo through many miles of wire was very wasteful. A great deal of the energy only made the wires warm, and making the wires warm increased the difficulty of pushing current through. It was soon discovered that the waste of electrical energy could be cut down if there was sufficient *push* or voltage at the source of supply. 11,000 volts were finally used; not that a greater pressure wouldn't have been better, but that

*From *Popular Science Monthly*, page 23, in the January, 1929, issue.

engineers didn't know how to handle currents at greater pressures. These tremendous electrical pressures resembled lightning and were as uncontrollable as lightning.

For many years after, scientists worked with laboratory lightning. Gradually, higher and higher voltages were generated and successfully handled. In 1900, 60,000 volts were being used in power plants. In 1923, an engineer showed how 220,000 volts could be safely sent over a cable. In 1925, voltages as high as two million were obtained; and to-day we can generate a pressure of 5,000,000 volts! The higher the voltage the further you can send electric currents without waste.

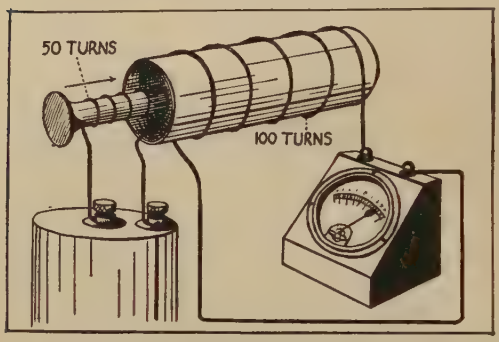
© *Underwood & Underwood*

81. One hundred million volts!

Of course, we are still far from being able to handle real lightning. The voltage of some lightning flashes goes up to 100,000,000 or more. If only we could control such electrical pressures! Not only should we make the world a safer place to live in but we should get, without the trouble of generating it, a tremendous amount of electrical energy that we could put to useful purposes. Steinmetz, the great electrical wizard, was at work on this very problem when he died a few years ago.

Perhaps you have been wondering how the pressure of electric currents is increased. Dynamos themselves can not do it. The armature coils would soon burn out if we tried it. We shall have to depend on a device outside the dynamo. We must have a method of changing one kind of current into another. We must learn how to change a low pressure into a high pressure. This knowledge will prove useful not only with dynamos but with radio sets, in which tiny variable currents carrying speech and

music must be made more forceful if we want to fill the room with sound. We shall use this knowledge in X-Ray machines, in automobiles, in ultra-violet machines, in telephones, and even in the so-called "medical batteries" which we find in hospitals, and in the "shocking machines" on sale in toy shops.



82. Moving an electromagnet near a coil.

To understand how one kind of current can be used to produce another kind we must again go back to Faraday and his Principle of Induction. In fact, the device is called an *induction coil*. Another form of it is known as a *transformer*.

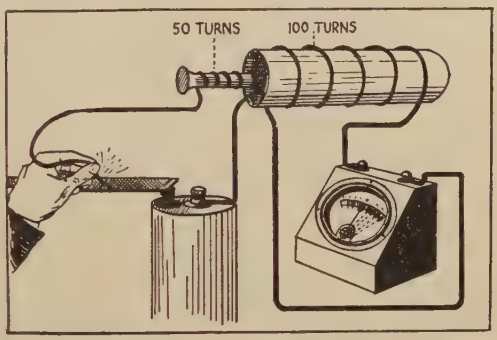
1. Variable currents may produce induced currents in nearby circuits

Here is an interesting experiment for you to try. Wind about fifty turns of wire around an iron nail. Get your electromagnetic coil (see figure 9 on page 7), and connect its ends with the electrical measuring instrument you used in Chapter VI. See figure 82. You will recall that moving a magnet near this coil induced a current in the coil. Now, instead of moving a magnet, move the coil which you have just wound around the nail. Is any current induced? Of course not. This nail will be a magnet only when current flows through its coil. Therefore, send current from a cell through the coil. Now the pointer jumps!

Let's try it another way. Disconnect one end of the coil. Place the coil inside the big electromagnet coil which is connected with the measuring instrument. Connect again the end which you removed from the cell. Strange how the pointer jumps, as if the magnet were moving. Disconnect. It jumps again. Make and break the circuit from the cell to the nail-coil. The pointer swings violently to and fro.

Still another experiment. Do you remember how, in Chapter VIII, you made a variable current with a file? See page 90. Cause a variable current to flow in the nail-coil as it lies inside the big coil. Again the pointer moves. See figure 83.

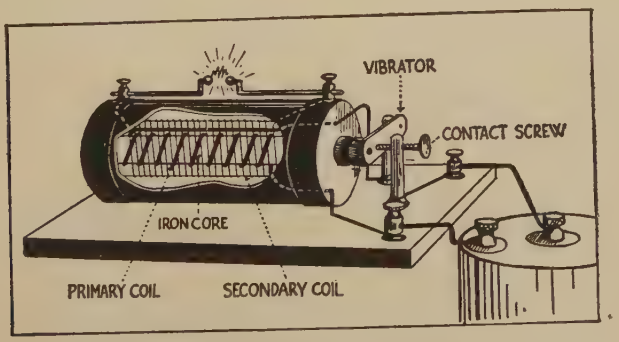
There is one conclusion which can be drawn from these experiments. A variable current in one coil acts like a fluctuating or moving magnet. If this fluctuating magnet is near another coil, a current will be induced in the second coil.



83. Variable current induces flow in nearby circuit.

2. The induction coil is a device to produce induced currents

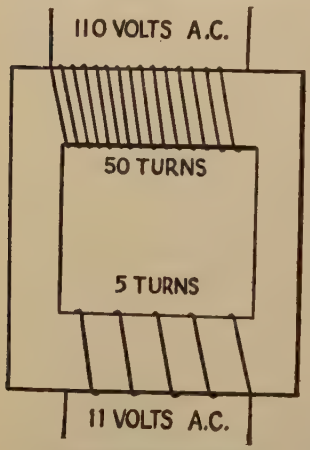
You must know some boy who has a shocking machine. Get him to bring it to class, so that you can all experiment with it. Perhaps your teacher has an induction coil, which is really the same kind of device.



84. Parts and construction of an induction coil.

Examine it carefully. See figure 84. Note that there are two terminals at the side with which the battery is connected and

two terminals at the top where the shocks and sparks are obtained. It is a good guess to say that these four terminals are the ends of two coils, one inside the other. The side terminals lead to the *primary* coil. The top terminals lead to the *secondary* coil. Another part should interest you. At the side, just above the primary terminals, there is a little vibrator. If you examine it carefully it will remind you of the vibrator of an electric bell. We studied how this vibrator worked in Chapter III. See page 39. Now look at the diagram, figure 84. In it you will see that the battery current flows through the vibrator and the primary coil. It will act like a bell, with the vibrator making and breaking the circuit. The fluctuating magnet thus produced will induce a current in the secondary coil.



85. Transformer with ratio of 10 to 1.

Let us suppose that there are 100 turns of wire in the primary coil and 10,000 turns of wire in the secondary coil. This is a ratio of 100 to 1. According to the law of induction the pressure of the current induced in the secondary coil will then be 100 times the pressure supplied to the primary coil. If you use a six-volt battery, you will get a pressure of 600 volts at the terminals of the secondary coil. With such a pressure, even the resistance of the air will break down, if the gap between terminals is not too great. It takes about 5,000 volts to break down the resistance of an air gap one inch long. With your induction coil you may get a spark one-quarter of an inch long. In that case, how many volts of electrical pressure are there induced in the secondary coil?

Lightning flashes two miles long have been observed. Can you calculate what the voltage must be in such a flash? Of course moist air does not offer such high resistance as dry air, and in a storm the air is very humid. You can increase the length of the spark in your induction coil by letting the steam from boiling water pass up through the air gap between the terminals.

3. The transformer is a kind of induction coil

If you were ever fortunate enough to get an electric train outfit for Christmas, you will remember the transformer that went with it. We can't be quite certain about this, however; for if you live in a district where direct current is supplied you did not use a transformer but merely a current reducer. Also, we are referring to train outfits that are connected with the light socket and not with batteries.

86. A high-voltage transformer. Coils are immersed in oil.

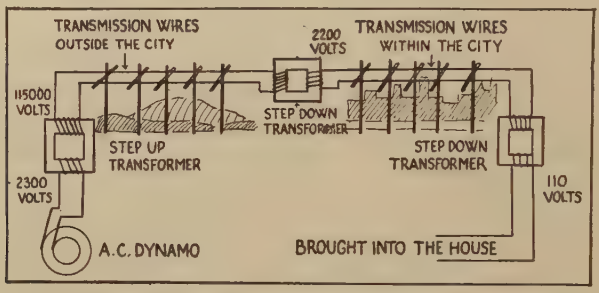
At any rate, a transformer is used to reduce the 110 volt electrical pressure with which every house is supplied to a pressure which will not shock the boy when he plays with his train, or burn out the house fuses whenever he makes wrong connections. Six to twelve volts are safe.

The transformer has two coils, a primary and a secondary. The vibrator, however, is not present. It isn't needed, if the primary coil is connected to an alternating current supply. The only purpose of the vibrator is to provide a fluctuating current. Alternating current is sufficiently fluctuating, as we saw in the last chapter.

Now, how does a transformer reduce the pressure of the house current? If the primary coil is wound with ten times as many turns as the secondary coil, the induced current will have one-tenth as much pressure as the current supplied to the primary. One-tenth of 110 is eleven; which is a voltage safe enough for boys to play with. See figure 85.

Recently, we have been doing away with batteries to ring door-

bells, elevator signals, and dumbwaiter buzzers. Replacing the batteries every few weeks is a nuisance. The same kind of transformer used in the toy train outfit has therefore been installed for the bell system of apartment houses. The 110 volts are reduced by these transformers to a small voltage which will not burn out the wire coils in the bells and buzzers.

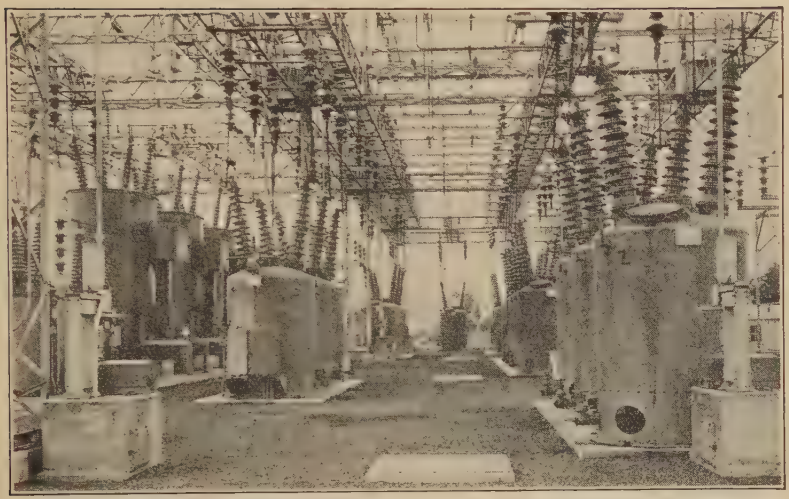


87. Bringing voltage from generating station to the home.

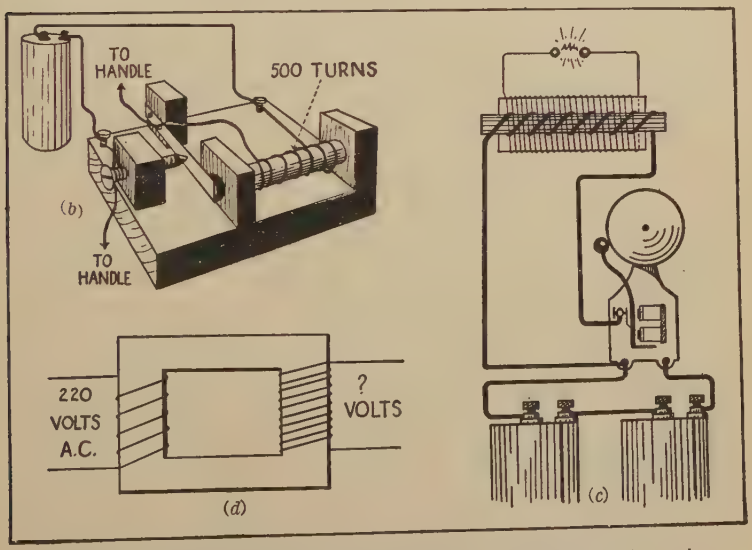
The greatest use of transformers, however, is in "stepping up" dynamo voltage so that the current can be sent economically to distant places. Of course, the dynamos must be alternating current dynamos. Perhaps you can now see why most parts of our city have A.C. current. It is just as good as direct current (D.C.) for most purposes and very much cheaper to generate and distribute.

Dynamo current is often generated at a pressure of 2,300 volts. If this pressure is applied to the primary of a transformer and the secondary in the transformer has 50 times as many turns in it as the primary, the electrical pressure induced in the secondary will be 115,000 volts. See figure 86.

Out in the suburbs it may be safe to transmit 115,000 volts, though occasionally we hear of people who touch these "live" cables and are shocked to death. As the power line approaches the city, another transformer is used, this time to "step-down" the voltage to 2,200. These cables now run under the street pavement and into the cellars of buildings. There the current flows into another "step-down" transformer in which the ratio of turns is 20 to 1. The voltage is now reduced to 110 and at this voltage enters our homes. See figure 87.



(*a*) Outdoor lightning arresters to protect transformers. Why this special precaution?



(*b*) Make this simple shocking coil or medical battery, and bring it to class.
(*c*) You can use the vibrator of a bell to make a shocking coil.

88. PROBLEM PICTURES.

HOW MUCH DO I REMEMBER?

A

Of the following, which are true of the induction coil, which are true of the transformer, which are true of both, and which are true of neither?

1. Is used to change a current of low voltage to one of high voltage.
2. Changes alternating to direct current.
3. Is used to generate electric sparks.
4. Is used to convert a current of high voltage into one of low voltage.
5. Has a primary and a secondary coil.
6. Helps to send current over great distances.
7. Needs an alternating current in order to operate.
8. Is used to run electric toys from the house supply of current.
9. Is made of one continuous wire wound into a coil.
10. Is used in order to permit the ringing of bells with the house current.
11. Is used to "step-up" dynamo currents.
12. Has a spark-gap.

B

Pick out the correct completion in each case. Write your answers on a sheet of paper so as not to mar the book.

1. The waste of electrical energy in the flow of electricity through very long cables can be cut down by

   (a) using the induction coil; (b) making the dynamo armatures move faster; (c) increasing the voltage of the current.
2. Variable currents may produce induced currents in nearby circuits because

   (a) a transformer is used; (b) the variable current acts like a fluctuating or moving magnet; (c) it is magnetized by induction.
3. The induction coil contains

   (a) 2 terminals; (b) 4 terminals; (c) one coil; (d) two coils.
4. The induced current flows through the

   (a) primary coil; (b) secondary coil; (c) vibrator.
5. The vibrator is used in induction coils

   (a) to make a sound indicating that the coil is operating; (b) to make and break the circuit; (c) to make the current in the primary coil fluctuate; (d) only when the current used is D.C.
6. A nine-volt battery is connected with a primary coil of fifty turns. If the secondary coil has 2,500 turns, the voltage of the induced current will be

   (a) 9/50; (b) 50; (c) 450; (d) 600.
7. The secondary coil of a transformer will have more turns than the primary

   (a) never; (b) always; (c) only if it is a "step-up" transformer; (d) only if it is a "step-down" transformer.

8. In the country the cables carry current of higher voltage than in the city because

   (a) the current voltage is reduced on entering the city for the sake of safety; (b) the cities are not properly equipped with transformers; (c) they need higher voltages in the country.

THINGS TO THINK ABOUT AND FIND OUT ABOUT

1. Find out how induction coils and transformers are used in your school building. In your home.
2. Find out how an aviator's inductor-compass works.
3. What precautions does a lineman take when he climbs up a pole to repair a transformer?
4. Make a list of the uses to which transformers and induction coils have been put.
5. Find out about the life and work of Ruhmkorff. Of Tesla.
6. What is the difference between a "step-up" and a "step-down" transformer?
7. Why may a "live" wire kill a person?
8. Fred has an induction coil which generates 1,000 volts. It is not at all dangerous; yet, the 500 volt third-rail in the subway is deadly. Why?
9. Why are transformers sometimes immersed in oil?
10. Why is the soft iron core of a transformer made up of many iron sheets rather than of one solid piece of iron?
11. What metal is used at the vibrator contact point in an induction coil?
12. Could you use a transformer to "step-up" the voltage of a battery? Why?

THINGS TO DO AND MAKE

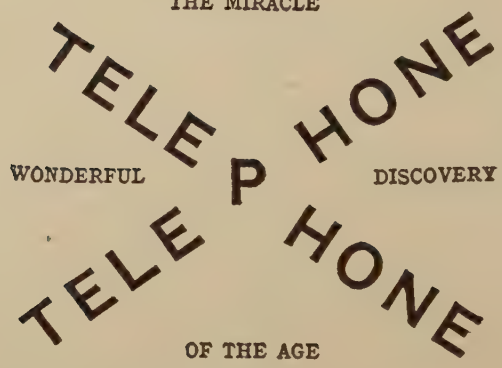
(The letters and page numbers refer to the books listed on page 18.)

1. A "loaded" door-bell button to shock an unwelcome visitor. Book F, page 31.
2. A surprise shocking-chair. Book F, page 307.
3. Some weird effects with an induction coil. Book F, page 261.
4. Interesting experiments with an induction coil. Book C, page 209; Book J, page 85.
5. How to make an induction coil. Book C, pages 194 and 199; Book E, page 118; Book F, page 282; Book G, page 89; Book I, page 138; Book J, page 70.
6. A buzzer as a shocking coil. Book F, page 69.
7. How to build "step-up" and "step-down" transformers. Book C, page 221; Book E, page 186; Book F, page 227.
8. How to make a transformer operate a night-light. Book F, page 49.
9. Using a transformer to operate an etching pen. Book G, page 199.

CITY HALL, LAWRENCE, MASS.

Monday Evening, May 28

THE MIRACLE



OF THE AGE

Prof. A. Graham Bell, assisted by Mr. Frederic A. Gower, will give an exhibition of his wonderful and miraculous discovery **The Telephone,** before the people of Lawrence as above, when Boston and Lawrence will be connected via the Western Union Telegraph and vocal and instrumental music and conversation will be transmitted a distance of 27 miles and received by the audience in the City Hall.

Prof. Bell will give an explanatory lecture with this marvellous exhibition.

Cards of Admission, 35 cents
Reserved Seats, 50 cents

Sale of seats at Stratton's will open at 9 o'clock.

CHAPTER X

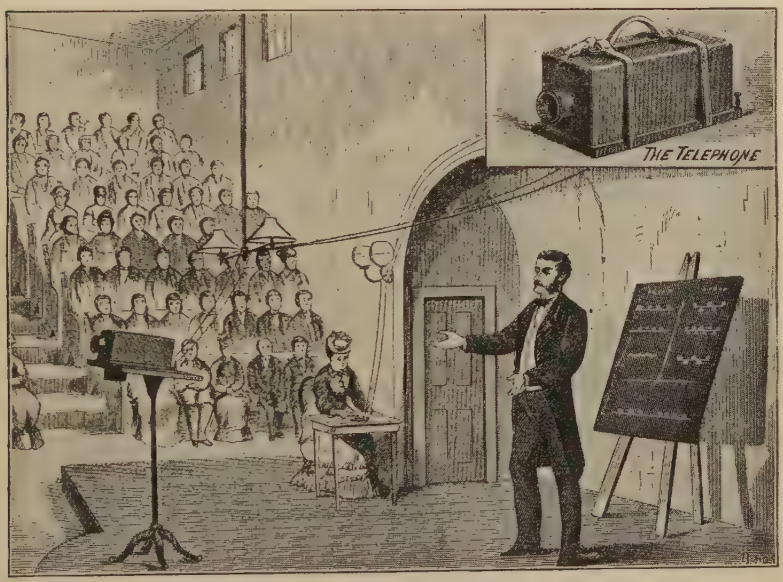
THE TELEPHONE

On May 28, 1877, there was considerable excitement among the people of a small city in Massachusetts. There was no war at the time, no crime had been committed, and there was no great election or football game—there was not even a circus in town. What was the excitement about? A professor was to deliver a lecture that night in the City Hall!

You will probably laugh when you read this. Why all the fuss? Such an event in the city where you live would hardly create a stir. Life is so full of exciting things nowadays that one lec-

ture more or less makes little difference to any one. Newspapers have to be urged to find space for a lecture announcement and when it appears you may hunt a long time before you find it —somewhere on page 36 or so!

But 1877 was a long time ago. Things were different then. In 1877 your grandfather was a boy of about your age. Let us think of him as living in the town referred to above. On the afternoon of May 28 he takes a stroll along Main Street to see the sights. Soon he finds himself in a crowd gathered around a large placard, a copy of which you can see on page 106.



89. Alexander Graham Bell delivering his lecture.

How can your grandfather resist the temptation to buy a ticket at once? That evening finds him seated up front, eagerly awaiting the great lecture and the exhibition. The professor finally appears. He is a fine-looking man and speaks well. He explains this invention of his. People listen; but most of what he says is either not understood or not believed. The real thrill is the exhibition.

The professor points to a box-like affair on the table. He

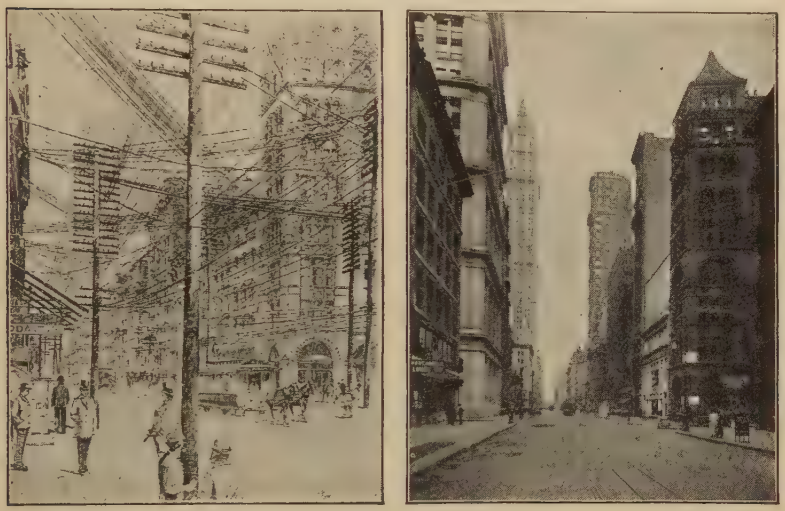
shows some wires that connect it with a telegraph pole outside. He explains that his assistant, Thomas A. Watson, is now in Boston waiting for his signal to begin to speak. He bends over and speaks into a horn, "Ahoy! Mr. Watson! We are now ready to listen to you." After a moment or so the audience is startled to hear the sound of speech mixed with a great many clicks and growls which we to-day should describe as "static." "Good evening," says the box. "How do you do?" "What do you think of the telephone?" "Now," says Professor Bell, "I will ask Mr. Watson to sing a song." And Mr. Watson, in a rooming-house in Boston, in his shirt-sleeves and muffled in a blanket so that his landlady will not hear the racket, yells "Yankee Doodle" into his telephone. The audience hears it faintly and applauds it wildly. Everybody goes home satisfied and enthusiastic about the wonder of the age—the Telephone. See figure 89.

In 1870 the telephone was only an idea in the mind of a young dreamer. In 1875 it had become an experiment. In 1877 it was a vaudeville performance. In 1880 it was a useful device in more than 30,000 homes and offices. Since that time it has assumed a vital rôle in our existence. During the year 1928, 23 billion messages were sent by telephone in the United States. An invention for which one company refused to pay $100,000 is now worth $2,783,000,000.

If all the telephone cables running under Broadway were to be put on telegraph poles we should need ten lines of poles. Each pole would be as tall as the Woolworth Building, each would carry 300 cross-arms, and each cross-arm would support ten wires. In the two illustrations on page 109 you will find an interesting comparison. Note what Broadway looked like in 1890, when only 500 telephone circuits were needed.

The history of the telephone is one of the most fascinating stories of science. We can hardly find space here to tell you of all the interesting things that happened to Bell, to Watson, and to others who shared in the development of talking over wires. Every one of you should write at once to the Information Department of the American Telephone and Telegraph Co., 195 Broadway, New York City, for pamphlets and other literature on the telephone. You will be well repaid.

The origin of the invention was an idea that we can trace to Oersted, Henry and Faraday. You will recall (Chapters II and III) how Oersted and Henry showed that currents flowing in a wire will exert a magnetic attraction. From their experiments came the electric bell. In 1870 a German scientist,

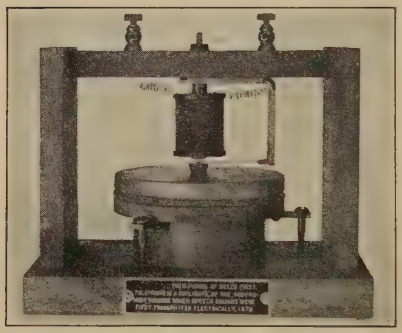


90. Broadway, New York City, in 1890 and in 1923.

Helmholtz, who was studying the science of sound and music, used electric bells in which the vibrators were tuning forks. Alexander Graham Bell heard about these electrical tuning forks and was fascinated by the idea. Bell was a student and a teacher of speech. Anything that had to do with the making of sounds interested him. Having just learned of Faraday's experiment in which a moving magnet induced current to flow in a coil, he was struck with the idea that Helmholtz's vibrating forks were really magnets moving in the presence of coils. Was their motion inducing currents? Could electric currents be made to vary in accordance with human speech and music? If he could generate such variable currents he could improve on the telegraph. He would actually transmit human sounds, instead of clicks, over a wire.

Unfortunately, Bell knew little about electricity, and he felt this very keenly. It is told that he once came to Joseph Henry and confided in him his great idea, adding that he wished he really knew something about electrical things. Henry's reply was "Get it!" referring of course to a knowledge of electricity. Bell set out to "get it." Like Morse, he sacrificed his real profession and devoted all his time to his experiments. With him was always Watson, a great mechanic and instrument maker.

They were working one hot afternoon with a device known as a "harmonic telegraph." It resembled Helmholtz's vibrating tuning forks, except that they used pieces of clock-springs instead of forks. Bell's idea was to perfect a system of telegraphy by which many messages could be sent over one wire at the same time. Theoretically, it should have worked. Practically, it had been giving them trouble for months. Bell's financial backers wanted this device for the money that was in it; and, though Bell was thoroughly disgusted with it, he felt it his duty to continue. Without much interest Watson adjusted the vibrators in the attic as Bell tuned his in the cellar. At this moment an accident occurred. The contact screw on one of Watson's vibrators melted fast to the vibrator, due to the heat of the electric spark. (You have all seen the spark at the vibrator in a bell.) This enabled a continuous current to flow through the coil and the stage happened to be set so that a magnet was near a coil. Watson reached out to pluck the vibrator loose. When he did so he *moved a magnet in the presence of a coil.*

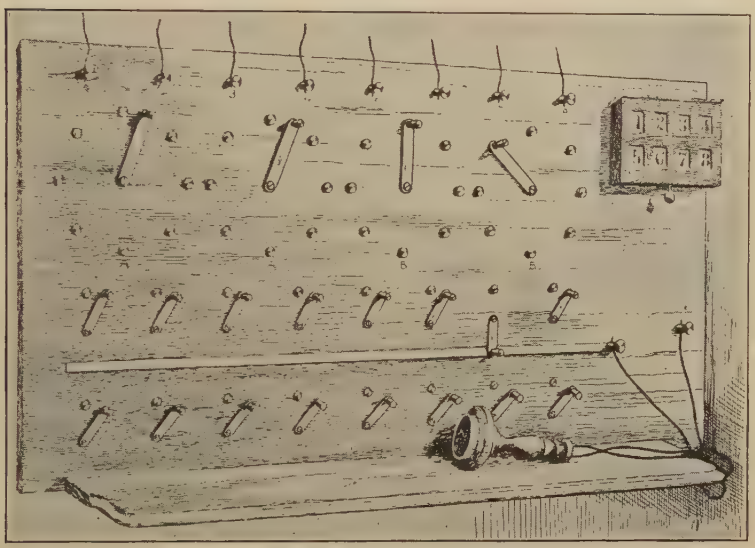


91. Bell's first telephone.

Suddenly Watson heard a shout. Bell came dashing up the steps, excited and yelling, "What did you do then? Don't change anything! Let me see!" Bell had heard in the cellar the sound of Watson plucking at the vibrator. The telephone had been born. In hundreds of ways Bell and Watson repeated the ex-

periment, and with greater and greater success. It was not long after, that the first words ever spoken over a telephone were heard by Watson. They were, "Mr. Watson, please come here, I want you." In 1915 Bell, in Arlington, Va., spoke the same words over the telephone to Watson, who was in the Hawaiian Islands, a distance of 5,000 miles.

There were others who added to the telephone to make it what



92. An early form of switchboard

it is to-day. Edison and Blake devised a mouthpiece, much more efficient than a receiver used as a mouthpiece. George W. Coy devised the first switchboard for connecting subscribers with each other, and Charles E. Scribner perfected it with more than 1,000 patents. Strowger and Keith then devised the automatic switchboard and "dial" telephone which is to-day gradually doing away with the telephone operator. Carty devised methods for eliminating stray noises that played over telephone circuits night and day, and Pupin invented the "loading coil" with which long distance telephony became practical and cheap enough for everybody to use. Recently the vacuum tube has been intro-

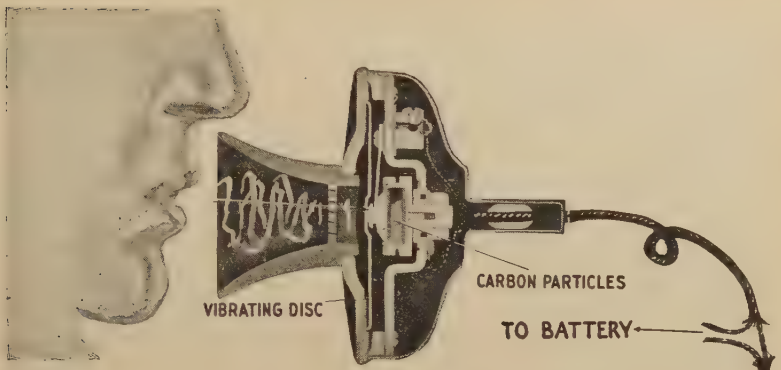
duced into the telephone and radio has been called on to cooperate with the telephone in bridging vast distances across which wires would be either impractical or impossible.

In fifty years, that attic to cellar telephone has multiplied so rapidly that it takes five million telephone directories each year to tell us the names of all the people who own a telephone.

93. A modern telephone switchboard.

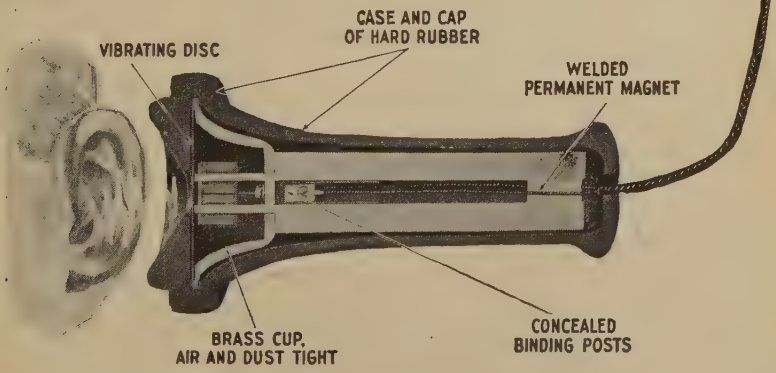
1. The essentials of a telephone are a transmitter, a circuit, and a receiver

Many of the essential parts of a telephone can be examined in your own telephone at home. Of course, it would not be wise to tamper with the instrument, for, in the first place, it would interfere with your service, and in the second place, the instrument belongs to the telephone company and not to you. However, with the aid of careful observation and of the pictures shown on page 113, you should be able to learn a good deal about it.



First, the *transmitter* or mouthpiece: This is a hard rubber horn which screws into a round base. Behind it is a metal disc or diaphragm. If you will examine the picture, figure 94, you will see that any movement of this disc back and forth will push it against, or release its pressure on, a number of carbon particles in a container right behind the disc.

Second, the *circuit:* This includes a source of current at the exchange and conducting wires from the source to your instrument and back to the source. You will notice that the hook on which the receiver hangs moves up

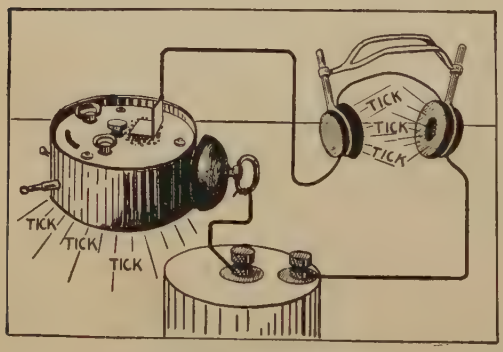


when the receiver is removed. When the hook is kept down, the bell-ringing circuit is ready to operate and the speaking circuit is broken. When it is lifted the ringing circuit is broken and the speaking circuit is ready to operate.

Third, the *receiver:* Since a radio head-set is really two telephone receivers attached to each other, you may find it convenient to examine one of these. Unscrew the cap of one of the radio receivers. You will find an iron disc which is attracted by a permanent horseshoe magnet. Around the ends of this magnet are wound two coils of wire. The coils are connected and the two remaining ends are brought out at the rear of the receiver; in a telephone they lead to the telephone circuit.

2. The transmitter enables sound vibrations to set up a variable current in the circuit

If you can get a radio head-set, an alarm clock, a piece of copper, and a few carbon particles, you will enjoy doing the following experiment. Lay the clock face downward on a table. Scatter a few particles of carbon on the metal back of the clock. You can get carbon particles by cracking up a carbon rod from an old cell. Now lay a small square of copper over the particles. Connect one wire with the copper and another with the metal frame of the clock, and stretch these wires to another room where the ends can be connected with a radio head-set. Connect a dry cell in the circuit. If you adjust the copper over the particles very carefully you will hear the clock ticking in the radio head-set. See figure 95.



95. How a transmitter works.

In the experiment above you have really made a telephone

transmitter. This is the explanation. The source of current (the cell) sends a direct current through the entire circuit. The flow is small because loosely scattered carbon particles offer great resistance. The tick of the clock, however, is a sound vibration and the metal back of the clock acts as a disc which vibrates in accordance with the sound made. If a word had been spoken, this disc would have taken up a vibration corresponding to the word. Now, these vibrations cause varying pressures against the carbon particles. When the particles are compressed they offer less resistance to the flow of current. As the disc vibrates, therefore, more current flows in the circuit; but this current must be a variable current since the pressure causing them is a variable one. Thus there is a current varying in accordance with a varying pressure, which in turn varies in accordance with the vibrations due to a sound. It might all be summed up in this way. When you say "Hello" into a telephone transmitter the disc vibrates in a "Hello" manner. The carbon particles are compressed in a "Hello" manner. This causes the direct current from the source to change into a "Hello" current.

3. The receiver causes the variable current to operate its disc and produce sound

Let us continue the explanation begun in the paragraph above. What happens when a current varying in accordance with the word "Hello" reaches the receiver? The permanent magnet in the receiver is holding the iron disc in place. It is motionless. Should the strength of the magnet change in any way, this disc would move either closer to or further from the magnet. Now comes the "Hello" current into the coils of the receiver. The coils become electromagnets and change the total magnetic strength which is attracting the iron disc. Furthermore, these changes are fluctuating in accordance with the word "Hello." The disc will then move back and forth in a "Hello" manner, reproducing the word "Hello" to the human ear held near it.

When Bell and Watson made their early experiments they did not use the carbon transmitter. They used the receiver both for talking and listening. If you want to see how this may be done

connect two radio head-sets with two long wires. You do not even need a battery for this. You can hold one receiver to your ear and another to your mouth, while your friend, out in the hall, does the same with his head-set. With such an arrangement you can talk to each other quite easily. As you talk into a receiver you cause the disc to vibrate in accordance with the sounds you make. The disc, being made of iron, is a magnet by induction. It is very close to the permanent magnet. As it vibrates, it is really a magnet moving in the presence of a coil. Current is therefore induced in the coil. This current varies with the movements of the disc. If the latter vibrates in a "Hello" manner, a "Hello" current is generated. When this current reaches the receiver at the other end, the word "Hello" is reproduced.

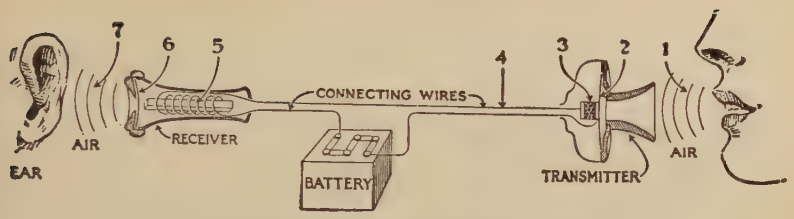
4. The telephone serves many uses in modern life

Twenty-three billion messages were sent over the telephone in 1928. That means about a thousand calls each second for twenty-four hours of the day, every day in the year. Its use has become tremendously important in the home, in business, in government, in the enforcement of law, in the pursuit of criminals, in facilitating transportation, and in the gathering and spreading of news.

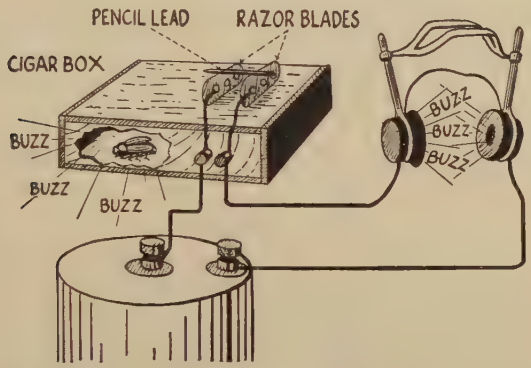
HOW MUCH DO I REMEMBER?

Decide on the word or words you would use to complete the sentences below, so that they become true statements. Write your answers on a sheet of paper so as not to mar the book.

1. The telephone was invented in the year .....
2. Bell's real profession was .....
3. ..... was Bell's assistant.
4. The essential parts of the telephone are .....
5. Edison's contribution to the telephone was .....
6. Lifting the receiver from the hook permits a ..... current to ..... through the line.
7. Sound vibrations cause this current to become .....
8. The ..... is really a high resistance to the flow of current in the telephone line.



(*a*) Explain what happens at the numbers.



(*b*) Telephoning the buzz of a fly. Make this apparatus and bring it to class.

(*c*) Bell's assistant. What is his name? Prepare a report on his life.

(*d*) Down in a manhole. Of what use are these devices in the telephone?

96. PROBLEM PICTURES

9. For a transmitter Bell used a .....
10. The operation of (the receiver, Bell's transmitter, the modern transmitter) is like the operation of a dynamo.
11. The receiver disc must be made of .....
12. The transmitter disc may be made of .....
13. Talking into a transmitter causes the disc to .....
14. Thus the ..... are alternately compressed and released.
15. This causes a ..... current in the line.
16. This kind of current causes the ..... in the ..... to vibrate in accordance with the original sounds.
17. ..... were the first words ever spoken over the telephone.
18. The harmonic telegraph was .....
19. Induction coils are used in the telephone to .....
20. The dial telephone was devised by .....

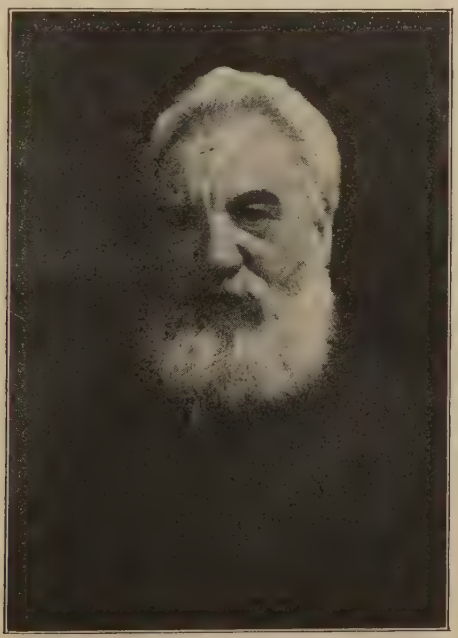
THINGS TO THINK ABOUT AND FIND OUT ABOUT

1. What is the meaning of the word, "telephone"?
2. After a visit to a telephone exchange, explain the following to your class:
   (a) How a call is received at the exchange.
   (b) How it is completed.
   (c) How it is timed and charged up to the subscriber.
   (d) The difference between the A and B switchboards.
3. Explain how speech may be transmitted with two receivers connected with wires, but without a battery.
4. How has the telephone aided the deaf?
5. Of what use is the radio vacuum tube in the modern telephone?
6. Of what use was the magneto in the old fashioned telephone?
7. How may one receive an electric shock while holding a telephone instrument?
8. List the advantages and disadvantages of the telephone as compared with the telegraph.
9. What is the purpose of the "hook" on a telephone instrument?
10. What are Elisha Gray's claims as the inventor of the telephone?
11. List all the men who have had some share in perfecting the modern telephone.
12. How does the United States compare with other countries in the use of the telephone?

THINGS TO DO AND MAKE

(The letters and page numbers refer to the books listed on page 18.)

1. How to build a telephone.
   Book C, page 179; Book E, page 234; Book G, page 160; Book J, page 60.
2. How to build a microphone.
   Book A, page 159; Book C, page 170; Book F, page 318; Book G, page 160; Book J, page 64.
3. How to build a telephone receiver.
   Book A, page 167.
4. Wiring a telephone.
   Book J, page 67.
5. A loud-speaking telephone.
   Book F, page 278.
6. A delicate sound amplifier.
   Book F, page 310.
7. An alarm that rings by sound.
   Book F, page 5.
8. Using a telephone as a circuit-tester.
   Book G, page 213.

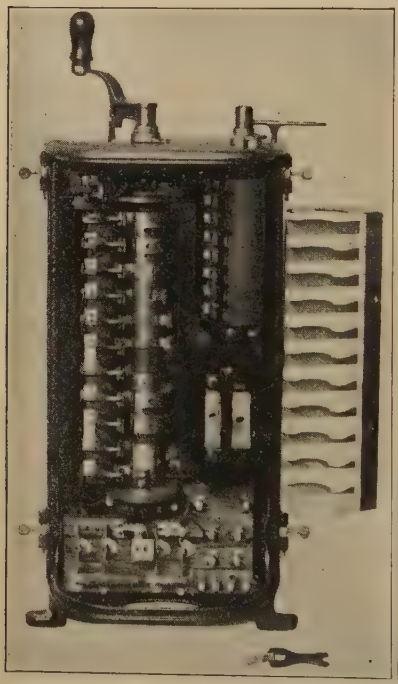


Alexander Graham Bell.

CHAPTER XI

THE ELECTRIC MOTOR

Did you ever stand on the front platform of a moving subway train, looking out into the dusty darkness? It is one of the many thrilling experiences in a great city. As you stand there with face pressed against the glass window, you somehow feel the tremendous power of the 300,000 pounds of steel as it hurtles through black space at a speed of sixty miles an hour. To your right is a little cubby-hole of a room in which sits the motorman. His hand controls the speeding monster and to his judgment is left the safety of ten car-loads of human beings.



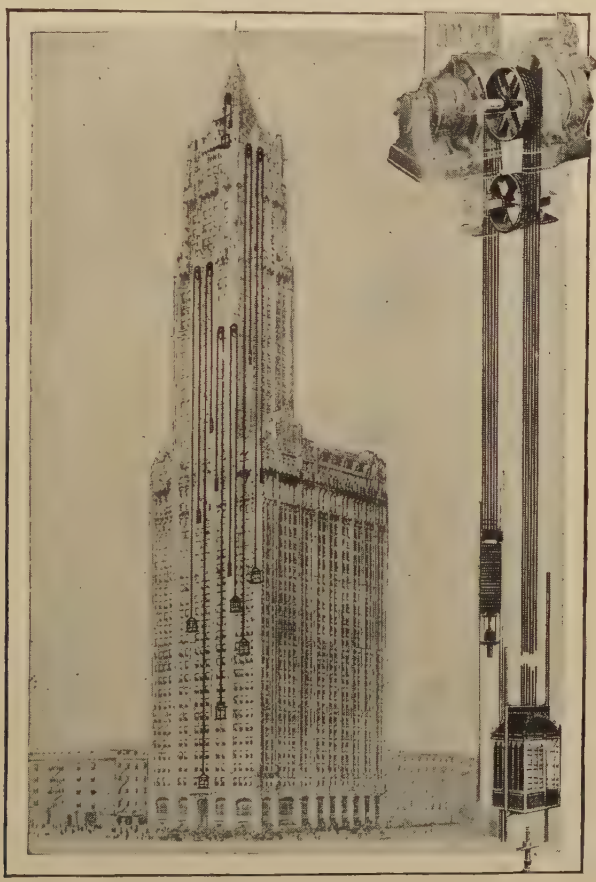
97. To control the speed of electric motors.

You can ride for hundreds of miles under a great city. Six millions of people crowded together in a small area need

98. Type of motor which drives a subway car.

special ways of moving about, particularly if they want to move quickly. Great as were the visions of Oersted and Henry and Faraday they never dreamed that their simple laboratory ex-

periments would some day make possible an electrified railway under ground. Electricity made the subway possible. An *electric motor* is the machine which drives the wheels that carry people from their homes to places of business and back.



99. The modern demand for up and down travel is met by the motor.

Offices, factories, and even dwellings are to-day housed in sky-scrapers. To reach the 20th, 30th and 50th floors we must be carried. We cannot walk. Here, too, we call upon electricity to

turn a motor that will lift us and lower us a dozen times a day. We cover nearly as many miles in up-and-down travel as we do in horizontal travel. See figure 99.

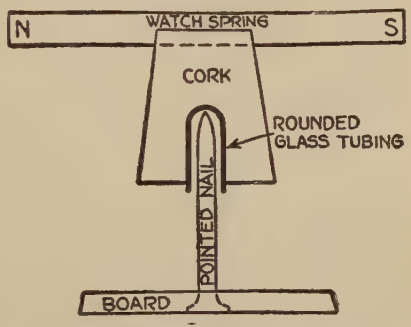
The electric motor has become an essential to modern existence. Trolley cars, the elevated, the subway, and skyscraper lifts are only a few of the uses to which electric motors have been put. To start an automobile you operate an electric motor. In the modern home you will find vacuum cleaners, electric fans, washing machines, dish washers, sewing machines, phonographs, massage machines, electric driers, and refrigerators all driven by motors. The wonderful electric signs which attract your attention perform their tricks with spinning motors. Escalators and hoists, derricks and cranes, printing presses and linotypes, grindstones and polishers, lathes and drills, stamping machines and cloth cutters, pumps and presses—all depend on the electric motor for their usefulness.

In an electric motor one magnet makes another one spin around. That seems like a simple idea which should have occurred to many men, especially after the work of Joseph Henry. However, it was not until 1837 that Davenport took out his patent on the electric motor, and not until 1888 that it was successfully used in a railway system.

You will be interested in the life and work of Tom Davenport. He was the village blacksmith at Brandon, Vermont, but he was far more interested in magnets than he was in horses and carriages. One day he went out to purchase some necessary iron for his shop. He came back with his eighteen dollars spent, but instead of iron he had bought an electromagnet. This kind of attention to business got him into difficulties, of course; but though he was always short of funds he was never short of ideas. One of these ideas resulted in a crude model of an electric motor. To insulate the wires of his coils he did not hesitate to use the silk of his wife's wedding-dress. It is a great pity that loyal Mrs. Davenport did not live to see the day when her husband's electric motor was used to lighten the burden of household drudgery. Before he died, however, Davenport had organized an electric company, built a model of an electric railroad, and applied his motor to a printing press.

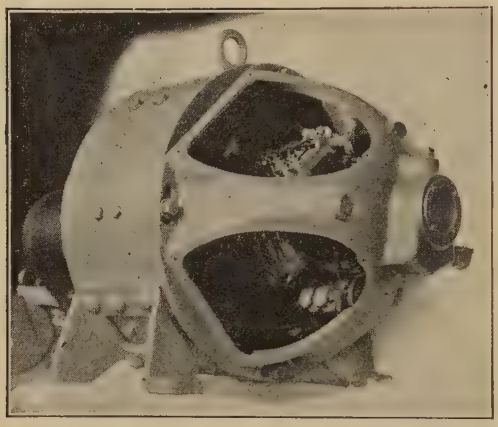
If dynamos had been invented twenty-five years sooner than they were, Davenport's railroad would have been a success. Unfortunately, the only way of getting electricity in his day was by chemical action in cells. One man, Professor Page by name, ran an electric car from Washington to Bladensburg, Md., using 100 cells. When he attained the wonderful speed of nineteen miles an hour his battery cracked and fell to pieces.

Failure seems never to discourage inventors. For forty years after Page's failure, hundreds of men tried thousands of experiments. With the coming of dynamo current and high voltages, these experiments began to bring results. In Germany an electric train was successfully operated from a central power station. One track served as the feeder wire and the other track as the return wire. Of course, the wheels on one side had to be insulated from the wheels on the other side. Next came a bus-like vehicle that received its current supply from two trolley wires overhead. No tracks were used in this case. Then some one thought of the scheme of using only one overhead power line with the tracks as the return wire to the dynamo. Most trolley lines are still of this type. In some big cities the power line is embedded in a ditch underground. A pole from the trolley sliding in the slot between the tracks makes contact with the power cable in the ditch.



100. With a magnet you can make the compass spin like a motor.

In 1890, New York City was already beginning to be crowded. Homes and places of business were spreading northward, on Manhattan Island. It became necessary to transport crowds of people from one place to another. At first one powerful trolley hauled a number of trailer cars. Then an engineer named Sprague showed how motors could be supplied to every car in a train, the control being centred in the first car. Sprague de-



101. An electric motor.

signed the first Manhattan elevated electric train, doing away with steam locomotives. In 1904 came the first subway. Every year, however, additional subways are being planned and built.

According to one encyclopedia, the rails in the trolley lines and subways throughout the United States would, if laid in one continuous track, reach twice around the earth. Enough fares are paid each year to provide more than one hundred rides for each one of our 120,000,000 people. Davenport's great dream has come true.

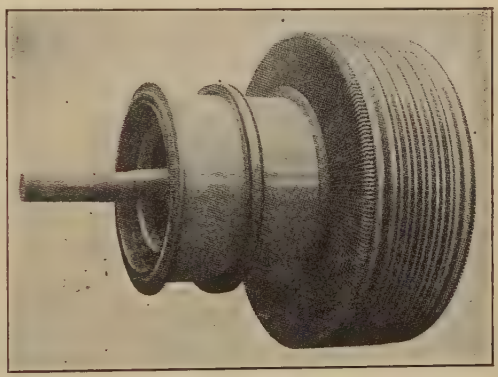
1. Magnetic attraction and repulsion may cause a freely moving magnet to rotate

Do you recall the magnetic compass needle which you made and used in Chapter I? You will need a large one for an experiment that will help you to understand the electric motor. If it will save you time, look at the diagram on page 123, which shows how a large compass needle can be made from materials that any one can find at home. As usual, mark the north-seeking end with chalk. When the compass needle has come to rest bring the N-end of a bar-magnet near the N-end of the compass. There will be a repulsion and the N-end of the compass will swing away. Just as the S-end of the compass swings by the N-end of the bar magnet, quickly twist the bar-magnet around so that its S-end is now near the S-end of the compass. There will again be repulsion and the motion of the compass needle will continue in the same direction. When the N-end of the compass next comes around, twist again. If you learn to do this properly you will soon have a spinning magnetic needle.

2. The essentials of a simple electric motor are field magnet, armature, commutator and brushes, and current

The first thing to do, if you wish to understand an electric motor, is to examine one carefully. Of course, there are many different kinds. They differ in size, in shape, and in certain features of construction; but they all have the same essential parts. If you have no motor among your toys and if none of your friends has one, examine the picture shown in figure 101; or, ask your teacher to let you see a motor.

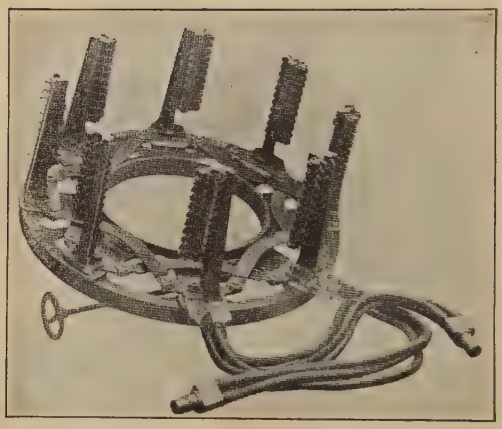
Notice, first, the *field magnet*. It is a large electromagnet with a soft iron core shaped so that it will enclose the rotating coil. In modern motors, this soft iron core forms almost a complete shell, so that very little of the inside is visible. See figure 60 on page 76.



102. The armature with commutator attached.

The moving coil is known as the *armature*. This is made up of a large number of turns of wire, in bundles, around a soft iron drum which carries a shaft at its centre. The shaft can rotate freely in bearings. You will often find oil cups over these bearings to reduce the friction. See figure 102 and also figure 61 on page 77.

You will notice that all the bundles of wire in the armature form one continuous coil. However, the ends of each bundle are also connected with a cylinder made up of copper strips which are insulated from each other, and which cylinder moves with the armature shaft. This cylinder is known as the *commutator*, and is divided into twice as many strips as there are bundles of wire in the armature. This gives two strips for each bundle, the strips for any one bundle being placed on sides of the shaft opposite each other. See figure 62.



103. The brushes which rest against the commutator strips.

Resting against the commutator are *brushes*, so placed that at all times they are in contact with the commutator strips. See figure 103.

Since both the field magnet and the armature are coils of wire, a *current* must flow through both in order that they may become magnetized.

Perhaps you have noticed by this time that the essential parts of a motor are like the essential parts of a dynamo. See page 76. They are almost exactly alike in construction. The real difference is that a dynamo must be turned in order to generate current, while a motor turns when current is supplied to it.

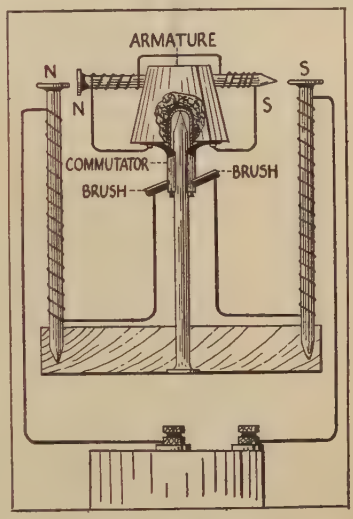
3. The magnetic attraction and repulsion between the poles of the field magnet and of the armature coils cause the armature to rotate

When sufficient current is brought to the brushes of a motor, there is a current flow through the field coil and also through one of the armature bundles. Thus, there are two electromagnets.

Immediately, there will be an interaction between these magnets. The N-poles and the S-poles will repel each other. The N-pole of any one will attract the S-pole of the other. The armature bundle will, therefore, move. As it moves, the brushes come at once in contact with new commutator strips leading to the next bundle of coils. The new bundle becomes magnetized and moves. The same action continues for all the bundles in the armature. The armature rotates continuously.

A homemade motor is not only a useful thing to have but a

good deal of fun to make. Look at figure 104. For a field magnet use two nails, each wound with about twenty-five feet of insulated wire. For an armature use a nail wound with about fifteen feet of wire, and stuck through a cork. Mount the cork on a point reaching up into a rounded glass tube embedded in the under side of the cork. This is the same method you used for the compass needle described in figure 100. Notice how two copper strips or pieces of tin-foil may be wrapped around the glass tube to serve as a commutator. The brushes are bare wires which rest against the commutator strips. If the current from a battery is connected with the brushes it will make the armature spin around at a great rate.

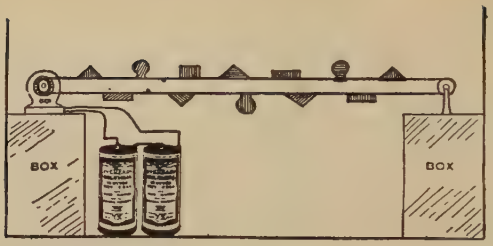


104. A motor every pupil can make.

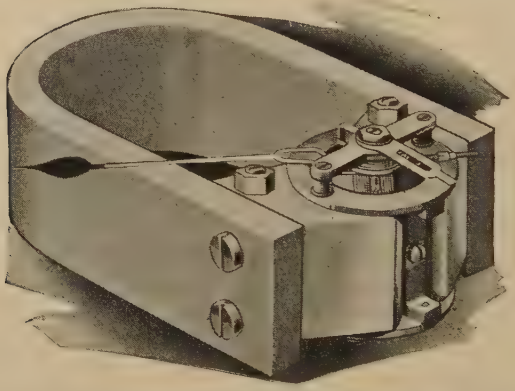
HOW MUCH DO I REMEMBER?

Decide on the word you would use to fill in the blanks in the sentences below, so as to make true statements. Write your answers on a sheet of paper so as not to mar the book.

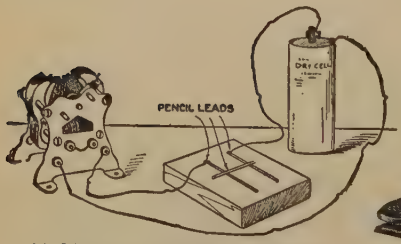
1. The ..... is the machine which drives the wheels of the subway train.
2. Five machines driven by electric motors are the following: .....
3. ..... was the first to patent an electric motor.
4. The motor could not be used widely until .....
5. Magnetic attraction and repulsion may cause a freely moving magnet to .....
6. The essentials of a simple electric motor are .....
7. The essentials of the motor which are also essentials of the dynamo are .....
8. In the dynamo ..... is produced by .....
9. In the motor ..... is produced by .....
10. The moving coil is called the .....



(*a*) Hook up your toy motor to operate a shooting-gallery.



(*b*) This is the working part of an electrical meter. Prove that a meter is a motor.



(*c*) Make this rheostat to control the speed of your motor.

(*d*) A motor used in an interesting way. Can you tell what this is?

105. PROBLEM PICTURES.

11. The field magnet has a ..... core.
12. The field magnets form almost a complete shell enclosing the .....
13. The shaft of the armature rotates on oiled bearings in order to.....
14. The current flows through the ..... and the .....
15. The ..... must be turned in order to generate current while a ..... turns when current is supplied to it.
16. The current enters the armature from the .....
17. The ..... is divided into strips, there being two strips for each coil of wire in the armature.
18. The armature is caused to rotate by the magnetic attraction and repulsion between the ... . and the .....
19. Two ..... attract each other.
20. Two ..... repel each other.

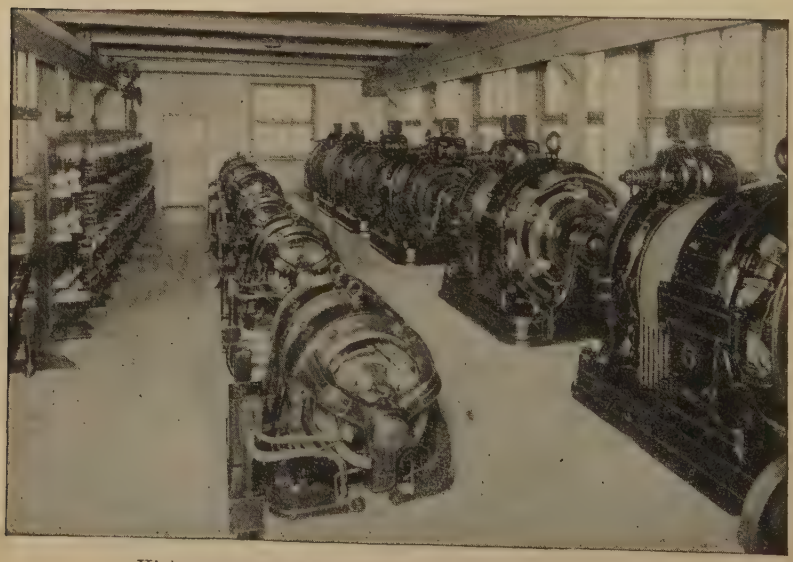
THINGS TO THINK ABOUT AND FIND OUT ABOUT

1. What is the meaning of the word "motor"?
2. Find out about the "series" motor. The "shunt" motor. The "compound" motor.
3. What is the difference between the A.C. motor and the D.C. motor?
4. Find out about Tesla's induction motor.
5. What is meant by a "universal" motor?
6. How is the motor used in the following: (a) electric fan; (b) hand drier; (c) vacuum cleaner; (d) electric signs; (e) barber shop pole; (f) electric massage machine; (g) President Coolidge's electric horse; (h) automobile starter.
7. What have the induction coil, the telephone, the dynamo, the transformer and the motor in common?
8. After starting a motor with a battery, why cannot the momentum serve to run a dynamo which will furnish power to keep the motor in operation?
9. If the motor had not been invented, what machines would the world now lack?
10. Why must some motors be started from a "starting-box"?
11. Why is a wattmeter like a motor?
12. Which is of greater value to the world, the electric motor or the gasoline engine? Why?
13. How is an escalator operated?
14. What is meant by a 2-horsepower electric motor?
15. Which is more efficient, a phonograph driven by an electric motor or one driven by a spring motor? Why?

THINGS TO DO AND MAKE

(The letters and page numbers refer to the books listed on page 18.)

1. A ten-cent electric motor.
   Book G, page 202.
2. A milk can vacuum cleaner.
   Book F, page 26.
3. A war tank that goes over the top.
   Book F, page 254.
4. A revolving Christmas tree.
   Book F, page 53.
5. A magic roulette wheel.
   Book G, page 247.
6. Building an electric railway.
   Book C, page 318; Book G, page 59.
7. A cork motor, a pendulum motor and Page's rotating armature.
   Book C, page 289; Book E, page 199; Book G, page 46.
8. How to make simple electric motors.
   Book D, page 180; Book G, page 128; Book H, page 350; Book I, page 148.
9. Testing for polarity in a motor.
   Book F, page 134; Book G, page 180.
10. A reversing switch for a motor.
    Book C, page 371.



High-speed motors for elevators in a modern skyscraper.

CHAPTER XII

ELECTRIC HEATING

For some time the tenants in an apartment house on S—— Street were being inconvenienced by the fact that the lights went out every evening. At about dinner time each day, just as they sat down to the evening meal, every one of the hundred families was annoyed to find itself in complete darkness. The janitor of the building—rather inexperienced in his business—was each night driven almost frantic by the numerous telephone calls and complaints. Groping his way to the switchboard in the dark cellar he would find the fuses blown. See figure 106. Replacing these with new fuses would bring the lights on again; but only to last a short time. This happened so often that he was greatly disturbed and really at a loss to know what to do.

When he discussed his problem with a friend, he received little sympathy. "Why don't you use coins instead of fuses?" asked his friend. "They're just as cheap and never fail. That is what I do, and I've never had any trouble."

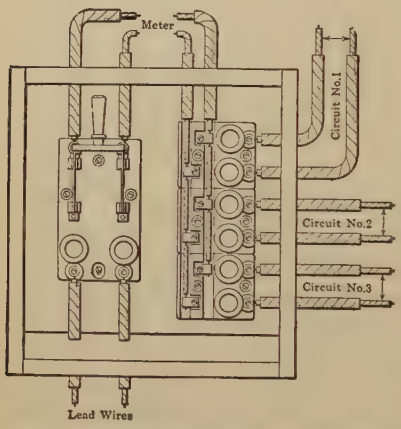
"That is not legal, is it?" asked the janitor.

"Well," said his friend, winking slyly, "that's what *I* do, anyway. *You* can do as you please."

That evening the lights went out again and the janitor, in desperation, put coins into the fuse receptacles instead of fuses. The lights went on and stayed on. Everybody was satisfied. Somewhere in the building, however, there was a defect in the wiring. The janitor had not discovered it and the tenant in whose apartment it was did not know of it. This defect was the real cause of the fuse-blowing. Now with the coins in place of fuses, great amounts of current continued to flow through the defective wiring. Hours passed. All the lights were still on, but one set of wires was getting warmer and warmer. It was now midnight. Most of the tenants were sound asleep. Embedded in the wall,

in many cases next to their beds, was a red hot wire. The heat soon cracked the plaster and paint. Through the cracks rushed air. A red hot wire, plenty of wooden lath, air to support combustion—it was not long before there was a fire in the interior of the wall.

The rest of the story you can well imagine. Many people were burned; some were suffocated, some were blinded, some were injured, homes were wrecked, property was damaged—all in the dead of night.



106. A switchboard panel for home electrical supply.

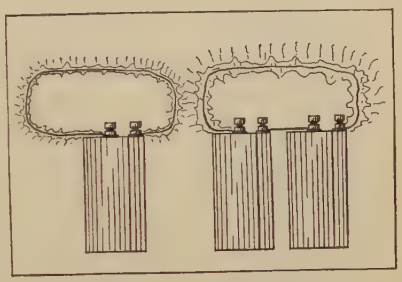
The flow of electricity is a wonderful thing. President Hoover once said that the flow of electric current does more for us in a day than all the banks do for us in a year. This is true, of course, so long as we are in control of this wonderful force. Let it once become our master instead of our servant, and in one brief moment it may undo all the fine things it ever accomplished for us. Every comfort and every convenience which electricity has introduced into modern life is coupled with a danger. This danger can be lessened and perhaps done away with through a better understanding of how electricity behaves. You must study carefully the different effects of the flow of electric current. In previous chapters you learned something about the magnetic effect. You studied also the chemical effect of the flow of electricity. In this chapter you will experiment with and learn about the *heating effect* of an electric current.

1. Heat is produced in conductors while current is flowing through them

If you have a fairly new dry cell and do not mind using it up rapidly, try this experiment. Connect a ten-inch cotton-covered wire with the terminals of your cell. Before long you will notice

that the cotton gets brown, then black, and finally begins to smoke. With very new batteries of two or more cells, you may be able, in this way, to make a thin iron wire red hot.

Here is something else which you can do. Compare the amount of heat generated when one cell is used with the amount generated when you use two cells connected in series. A storage battery, which gives the voltage of four cells connected in series, may even force through enough current to melt an iron wire. Do not do this often. It is very wasteful of the battery.



107. Increased current—increased heat.

Fasten a 12 inch piece of No. 30 copper wire to a 12 inch piece of No. 30 iron wire. Connect the loose ends of these wires with four cells connected in series. You will notice that the iron wire gets hotter than the copper wire. This is because iron resists the flow of electricity more than copper does. Good conductors, such as copper, require a much greater current flow before they get hot than do bad conductors, such as iron and nichrome. That is why copper is used in all electrical connections. One of the reasons why Morse and Bell had such trouble with their telegraph and telephone is that iron wire was the only kind obtainable in their day, unless one had a fortune to spend for copper wire.

In doing the experiments described above you will find that it takes a little time for the wire to get hot. In fact, the longer the current flows, the greater the amount of heat generated. To sum up what you have just learned, one can say:

First, that the greater the current flow, the greater is the amount of heat generated. See figure 107.

Second, that the greater the resistance which a conductor offers, the greater is the amount of heat generated.

Third, that the longer the current flows, the greater is the heat generated.

Of the three items above, the first is the most important.

2. Electrically produced heat is used in many devices

On page 135 you will find illustrations of several useful articles in which the flow of electricity produces heat. You probably have some of them in your home. Others you have seen. Embedded in each device is the so-called "heating-unit," which consists of a coil of high resistance wire. The wire used by most manufacturers is an alloy of two or more metals. An alloy of nickel and chromium is frequently used, giving us the nichrome wire to which we have referred elsewhere in this chapter. Whatever the wire used, it must have a high resistance, a high melting point, and it must not oxidize too readily in the air when at a dull red heat.

Devices of this type are becoming popular, because of their readiness, cleanliness, and convenience. They are costly, however. In New York City, the electric company charges at the rate of seven cents per kilo-watt hour. The watt is a unit of electrical power. Kilo-watt means 1,000 watts. If, then, the label on an electric iron reads 600 W., it means that your iron uses 600 watt-hours of electrical energy every hour. In two hours it will use 1,200 watt-hours or 1.2 kilo-watt hours. To use such an iron for two hours would cost seven cents x 1.2 which is 8.4 cents. If you will study the table given below you will get an idea of the cost of using various electrical devices.

DEVICE	WATTS	APPROXIMATE COST IN 5 HOURS
An electric bulb	15 to 60	½ cent to 2 cents
*A six pound iron	600	20 cents
*A toaster	400	14 cents
*A coffee percolator	500	17 cents
A washing machine	300	10 cents
An electric sewing machine	200	7 cents
A vacuum cleaner	200	7 cents
*An electric range	2,500	88 cents
An all-electric radio	100	3½ cents

Every item marked (*) is one in which there is a "heating-unit" of the kind described in this chapter. You can see in the table that these are the most costly items in the list. We are willing to pay more, however, for comfort and convenience. For ex-

ample, a heating-pad is more costly than a hot-water bottle; but an electric heating-pad can be applied to a sore muscle—can be

108. Using electricity in the home.

wrapped round it, in fact—and will keep a constant temperature all night.

3. Wires and other conductors often become so heated as to cause fires

When electricians install the wiring in a house they follow certain rules and regulations very closely. If they do not, their licenses may be revoked. These rules govern the size of wire to use for various purposes, the kind of wire, the kind of insulation, the number of outlets, the positions of these outlets, the way to enclose all wiring in fireproof containers, the kind and number of switches, and many other matters which affect our safety.

Above all, they see to the *fuses* which protect us against the possibility of fires started by electricity. Fuses are pieces of a soft metal alloy resembling lead. They melt at a low temperature. If you can get a piece of fuse-wire, try to melt it with a match.

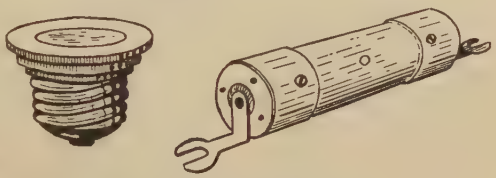
When a fuse is put into an electrical circuit, all the current must necessarily flow through the fuse, just as it must flow through every other part of the completed circuit. Since the current heats a conductor through which it flows, the fuse will get warm. If too much current flows, it will get hot and finally melt. When the fuse melts, the circuit is broken and no more current can flow. A five-ampere fuse will melt if more than five amperes of current are flowing in a circuit. A ten-ampere fuse will melt if more than ten amperes are flowing, etc. The maximum amount of current which a fuse will carry is stamped or printed on the fuse. Before putting in a fuse you should find out its carrying strength. Too great a carrying-strength is really no protection at all; such a fuse may permit the flow of a current large enough to start a fire.

In most homes fuses should carry no more than five amperes or ten amperes. The main fuses in the cellar are of course larger, and may carry as much as fifty or one hundred amperes.

When a fuse wire melts or "blows," there is a flash. It is necessary, therefore, to encase this flash in a fire-proof receptacle. In figure 109 you see the screw-plug type of fuse and receptacle. Through the small mica cover you can look in and see whether the fuse wire is melted or not. In figure 109 you also see a cartridge type of fuse, in which the wire is embedded in a fire-proof filling. This type of fuse is used in the switchboxes of most

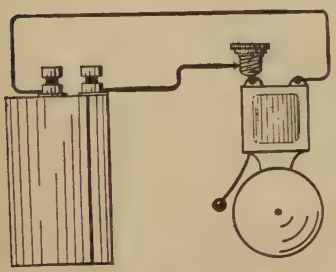
schools and is also the kind used in the control box of trolley cars.

The best way to test a fuse is shown in figure 110. If the bell rings the fuse is good. Set up such a fuse-tester and show it to your teacher.



109. Two types of fuses.

You may hear people speak of "short-circuits" which "blow" the fuse. You have learned that the less the resistance which a conductor offers, the greater is the flow of current. If while the current is flowing in a completed circuit, we should suddenly provide another path which has, let us say, $\frac{1}{5}$ of the resistance of the old path, five times as much current will flow along the new path as through the old. This new path is called a short circuit, that is, a path of low resistance. A loose connection in a socket will sometimes cause the two wires leading into the socket to touch directly instead of through the lamp filament or other device plugged into the socket. The resistance of a direct touch of this kind may be 100 times less than the path offered by the lamp or device plugged in. The sudden rush of 100 times as much current will melt the fuse wire.



110. How to test a fuse.

HOW MUCH DO I REMEMBER?

Pick out the statement or statements in List 2 which correctly explain the situations of List 1. Write your answers on a sheet of paper so as not to mar the book.

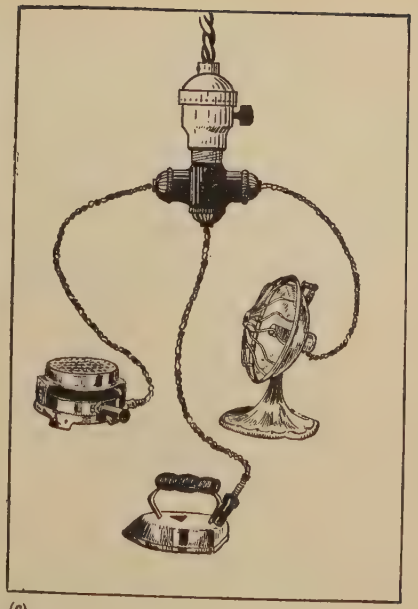
List 1

A. I uncoiled the wire which made up the heating unit of my old electric iron. It was very long.

B. The janitor has just put in a new fuse in the main fuse-box but the lights went out again.

(a)

(b)



(c)

(a) How is the heating effect of the electric current being used here?

(b) How does this picture illustrate the important ideas of this chapter and chapter XI?

(c) What will probably happen if you make such a connection? Is it safe? Why?

111. PROBLEM PICTURES.

C. The label on the lamp reads "40W."
D. The heating unit of the electric toaster is made of nichrome wire.
E. The government has had to make rigid rules for the arranging and insulating of house wires.
F. The boy tried to operate the big electric heater with his dry cell. He was not successful.
G. The fire started between the ceiling of the first story and the floor of the second story.
H. It costs more to operate a 6-lb. electric iron for an hour than a vacuum cleaner.
I. I connected the wire with my battery. At first it became warm, then hot.
J. The electrician could find no defect in the wiring. Still, the lights went out as soon as the switch was closed.

List 2

1. The watt is a unit of electrical power.
2. A ten-ampere fuse may have been used in the main fuse-box of the big apartment house.
3. A one-hundred-ampere fuse may have been used in the fuse-box belonging to a single apartment.
4. Wires and other conductors often become so heated that they cause fires.
5. The greater the current flow, the greater is the amount of heat generated.
6. The heating unit consists of a coil of high resistance wire.
7. The electric company charges a certain amount for each kilowatt-hour of electrical energy used.
8. The greater the resistance which a conductor offers, the greater is the amount of heat generated.
9. There may be some defect in the wiring.
10. A short-circuit may have been caused by a loose connection in a socket.
11. Heat is produced in conductors while current is flowing through them.
12. The longer the current flows, the greater is the heat generated.
13. Much electrical energy is used in the production of heat.
14. A penny may have been used instead of a fuse.
15. This lamp uses 40 watt-hours of electrical energy every hour it is used.

THINGS TO THINK ABOUT AND FIND OUT ABOUT

1. How are trolley cars heated?
2. Why are houses not heated by electricity?

3. Referring to the table on page 134 and assuming the cost of electricity to be 7 cents per kilo-watt hour, calculate the bill for using the following:
   Ten 40-watt bulbs, used for six hours each; one toaster, used for ten hours; one electric range, used for five hours; one electric iron, used for ten hours.
4. What are some of the causes for an unnecessary increase of the electricity bill?
5. Explain this statement: "Edison Co. official denies fire was caused by a short-circuit."
6. How is an electric furnace constructed?
7. What are some of the products of the electric furnace?
8. How are steel girders welded with electricity?
9. Why are the wires connecting a storage battery with the starting motor in an automobile so heavy?
10. Find out about Moissan. About Joule. About Watt.
11. Why are fuse receptacles, fuse-boxes, and wire conduits made of fireproof material?
12. What is meant by "cold" light?
13. The chain supporting the fire-shutter in a motion picture booth has one link in it made of fuse wire. Why?
14. Find out about the "hot-wire" ammeter.
15. How may electricity be used for cooling?

THINGS TO DO AND MAKE

(The letters and page numbers refer to the books listed on page 18.)

1. How to cook an egg with an electric lamp.
   Book F, page 79.
2. An electric heater for a toy steam-engine.
   Book F, page 316.
3. An inexpensive electric coffee pot. Book F, page 40.
4. A simple electric fireless cooker. Book F, page 1.
5. An electric toaster.
   Book E, page 142; Book F, page 8; Book I, page 140.
6. An electric cigar-lighter. Book F, page 196.
7. An electric soldering-iron. Book F, pages 118 and 272.
8. How to make fuses with which to protect batteries from short-circuits.
   Book C, page 111; Book F, page 140.
9. An electric water-heater. Book F, page 351.
10. How to make and wire table lamps.
    Book E, page 346; Book I, page 118.
11. How to do wiring around the house.
    Book E, page 299; Book I, pages 63 and 94; Book J, page 134.
12. Soldering a spliced wire. Book J, page 143.

CHAPTER XIII

ELECTRIC LIGHTING

"Wallace," he said, as they shook hands in parting, "I believe I can beat you making electric light. I do not believe you are working in the right direction."

It was Thomas Edison speaking to William Wallace, in the latter's laboratory. Edison had come to see an improvement on one of Sir Humphrey Davy's great experiments. Davy had once made an electric light by connecting 2,000 cells and permitting the current to flow through two pieces of coal. On separating the contact at the pieces of coal a brilliant spark had appeared. Wallace had now made a lamp in which carbon rods displaced the coal and dynamo current displaced the battery. It was known as the arc light and was eagerly adopted for lighting streets and other outdoor places. To take such a light into a home was impossible. It was too bright. It sputtered and flickered. It threw a ghastly light. It was difficult to handle.

Edison was impressed with Wallace's light but he felt that it could never displace gas for home illumination. The more he thought about the question the more fired he was by an ambition. What his ambition was you can gather from an entry made at this time in his "science note-book." Like Faraday, Edison kept notes on his experiments. His experiments with electric lighting cover 40,000 pages of written notes. Among these was one as follows: "Object, to effect exact imitation of all done by gas, so as to replace lighting by gas with lighting by electricity."

To begin with, he made a thorough study of the gas industry. He read every book and magazine he could get on the subject, visited every gas laboratory he could find, and discussed the subject with every prominent gas engineer. Soon he knew more about gas than any other man in the United States.

Then he began to experiment. As far back as 1845 an English-

man had heated a metal wire with electricity so that it became red hot. Since the wire soon burned up, this Englishman had even tried to enclose it in a glass bulb from which the air was extracted. But all his efforts had failed. Edison now had what all his predecessors did not have. He had dynamo current at high voltage. He decided to use this on a thin hair-like wire. His problem, however, was to find a wire filament which would glow brightly and be tough enough to continue to do so for at least 1,000 hours.

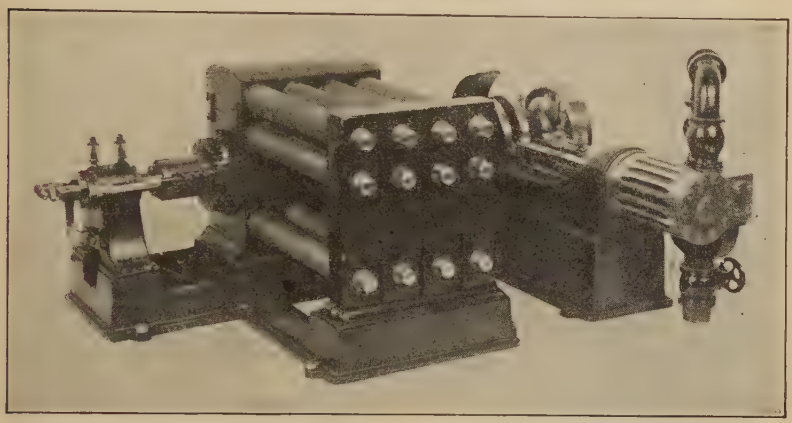
If ever a man showed persistence, patience, and courage, it was Edison in search of the right filament wire. In his laboratory at Menlo Park, New Jersey, he gathered around him about 100 men who worked with him day and night. Meals were brought to the laboratory. They even slept there, on benches and on tables, getting along on five or six hours' sleep a day. Once in a long while, for example, when Edison perfected a pump which extracted the air from a bulb so completely that only one-millionth of the air remained, he and his men would go off on a fishing trip for a day or so. Vacations, however, were very rare.

112. Edison's first lamp.

On October 21, 1879, success began to reward their efforts. A carbonized* piece of thread when used as a filament burned for forty hours. After this Edison began to carbonize everything. Rags, paper, cardboard, cocoanut husks, cork, flax, and even human hair were tried. One day Edison pulled a bamboo thread from a fan, carbonized it, and used it for a filament. It worked better than anything he had yet tried. This led him to a world-wide search for vegetable fibres like bamboo. He sent one man to China and Japan. An-

*By carbonizing is meant the driving off by heat of most of the elements that go to make up a substance, until only its carbon remains.

other went to Peru, Ecuador, and Colombia. Still another made a trip to the wildest parts of Ceylon and India. Three of his men spent five months in the marshes of Florida. One of his men spent fifteen months exploring parts of the South American jungle never visited by white men. Facing death from star-



113. A dynamo Edison used in the first lighting-plant in Pearl Street, New York City.

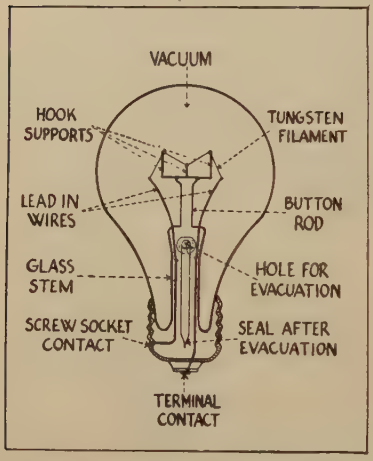
vation, snakes, diseases, and hostile Indians he continued his hunt for different kinds of fibres. The result of all these expeditions was to swamp Edison with materials with which to experiment. More than 6,000 different substances were tried. The best was a bamboo fibre from Japan; and for a long time Japan became the chief source of supply. In 1881 Edison sent to the Paris Exposition a dynamo which kept lighted no fewer than 1,200 of his bamboo filament lamps for several hundred hours.

In 1882, Edison designed his lighting plant in Pearl Street, New York City. From the time when he threw in the switch at 3 o'clock on September 4, 1882, to this day, New York City has never been without electric light. When one thinks of the millions of lamps now being used one might expect that Edison is being repaid in money for his years of toil. Edison himself once said that his electric lamp patents never brought nim any financial return. It has brought him, however, the everlasting grati-

tude of the whole world; for the Edison lamp has made the world a better place in which to live. See figure 113.

1. The essential parts of an electric lamp

A used-up electric bulb is an easy thing to get. You can learn a good deal about such a bulb if you examine it carefully. First, you see a round glass globe which tapers down to a stem. At the end of the stem is a metal screw-socket. You cannot always see inside the globe, because sometimes it is frosted. You must therefore break in. The safest way to do this is to break the globe under water. Fill a large bowl or pail with water, roll up your sleeves, immerse the globe under water with one hand holding the stem, and tap the globe with a hammer. If you succeed in just cracking the globe, you will hear a hissing sound. The water is rushing into the globe. Evidently the pressure of the air on the surface of the water is pushing the water into the globe. Some bulbs have an almost perfect vacuum inside. In that case the water will completely fill the bulb. After you have seen this inrush of water you can tap the glass harder and break away as much of the glass as you can. Now remove from the water what you have left. On examining this, you will see a filament of wire supported on a glass rod. See figure 114. The ends of the filament run down to the socket. One end is soldered to the side and the other to the middle. Note that the side of the screw-socket is insulated from the middle contact point.



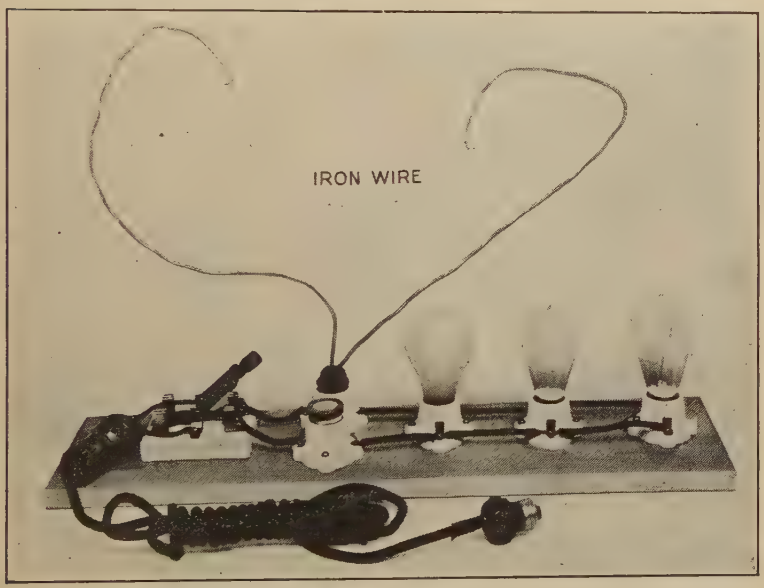
114. The modern electric lamp.

From your observations you can see that an electric lamp consists of a wire *filament* properly supported, enclosed in a *glass vessel* from which the *air has been removed,* and connected with

a *screw-socket* so that electricity can be made to flow through the filament.

2. The current heats the filament so that it glows

If you connect a piece of cotton-covered copper wire across the terminals of a cell, the wire gets hot enough after a while to



115. How to demonstrate that the electric current can heat a wire to make it glow.

burn off the cotton. This experiment you have already tried. If this wire is iron instead of copper, more heat is generated. It may even get red hot. In figure 115 you see a method of making a wire hot enough to glow.

In an electric lamp the filament wire is made of a highly resisting material. Edison used carbonized bamboo fibres. Nowadays we use tungsten wire. Tungsten is a highly resisting metal which can get extremely hot without melting. If there is sufficient electrical pressure, enough current will flow through the tungsten filament to make it white hot.

If there is no air to support combustion inside the globe, the filament will continue to give out light for a long while. The manufacturers guarantee lamps for 1,000 hours of use. In a vacuum, the tungsten cannot burn up, for oxygen is necessary for combustion. It can, however, evaporate. It seems strange to speak of a solid substance like tungsten evaporating. But we must bear in mind that the tungsten is made very hot. The molecules of the wire are therefore violently agitated. In time, they kick each other off the wire and strike the inside surface of the glass globe. There they remain, giving the globe a blackened appearance. After about 1,000 hours of use, some portion of the filament gets so thin from the constant loss of molecules, that it breaks. This break stops the flow of current and the lamp can no longer be used.

The fact that there is no air pressure inside the lamp hastens the evaporation of the filament. With no air molecules to restrain them, the filament molecules fly off more readily. This raises a puzzling problem. We cannot have the air around the hot filament, for that would cause it to burn up; and yet, we should like to have the restraining effect of the air molecules to reduce the evaporation. This made an engineer think of the scheme of leaving some of the air inside the bulb. He decided to remove only that part of the air which supports combustion —namely, the oxygen. When he did this, the remaining contents of the bulb was chiefly nitrogen. He was agreeably surprised with the result. His "nitrogen" lamp not only lasted longer than the "vacuum" bulb, but it consumed less current and gave out a much more brilliant light. Nowadays, the nitrogen lamp is commonly used for the very bright lights of Broadway, for window displays, and for lantern-slide machines.

It will be worth your while to remember the way in which a lamp filament acts. Read again the foregoing paragraphs. Mark well, the fact that *a heated filament is constantly throwing off particles of itself*. Edison noticed this when he first invented the electric lamp. He wrote about it in an article, calling attention to this discharge of particles from a heated filament. He asked scientists to find a way of controlling this discharge. He even pointed out that this discharge might be put to use in a

practical way. He was too busy at the time to work at the idea himself. If he had taken the time off to do so, he and not De Forest might have invented the radio "tube."

116. Using the electric lamp to attract attention to a skyscraper at night.

3. Electric lamps differ in construction, according to their use

Lamps differ as to the kind of filament wire they contain. A carbon lamp uses a carbonized fibre filament. You can still buy such lamps and they are cheaper than the tungsten wire lamps. However, they consume more current and they give a poorer kind of light. They are therefore less economical in the end.

Lamps differ as to the electrical pressure which is required to

light them. Flashlight lamps require a pressure of from two to six volts. Automobile lamps require from six to twelve volts. Christmas tree bulbs require about 15 volts. By stringing eight of them in series you can connect them with the usual 110 volts pressure of the home current supply. The household lamp requires 110 volts pressure. Lamps in the subway require from 220 to 500 volts.

Lamps differ as to the intensity of illumination which they produce. The greater the illumination, the greater is the electrical power consumed. Since electrical power is measured in *watts,* the wattage of a lamp will tell you how much light you can expect to get from it. Every lamp is labeled, not only with the electrical pressure at which it must be used, but with the number of watts it consumes. Thus, the mark 110V.–60W. on a lamp means that when this lamp is connected with a 110 volt source of current supply, it will consume electrical energy at the rate of 60 watts. The wattage of electric lamps ranges from about five watts to 2,000 watts. Household lamps range from ten to seventy-five watts. Window displays usually employ lamps of 100 to 250 watts. Lantern-slide machines contain 400 to 600 watt lamps, and theatre spot-lights use 1,000 to 2,000 watt lamps.

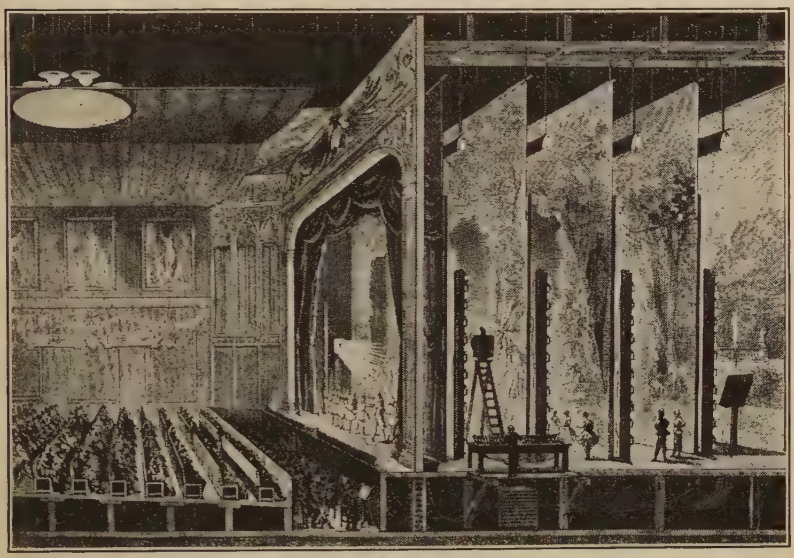
Lamps differ as to the kind of medium which surrounds the filament. We have already described the nitrogen lamp, in which the filament is surrounded by air from which the oxygen has been extracted. The more common medium surrounding the filament is a vacuum.

Lamps also differ in shape and in color. For decorative effects, lamps may be spherical, tubular, or pear-shaped, and may resemble candles, flowers, etc. The glass of the globe may be frosted, clear, or colored.

Finally, lamps may differ as to the size of screw-socket. Three standard sizes are common. The *miniature,* used in flashlights; the *standard,* for household use; and the *mogul,* used in some projection machines and in spot-lights. Hardware stores will frequently sell adapters with which large sized lamps can be made to fit small sockets, and vice versa. In automobile lamps, the screw-socket is not used. In this case they are slipped into a receptacle and caught in place by a projection pin on the lamp.

4. The electric lamp is in common and widespread use

Can you make a list of the many different places and devices in which electric lamps are used? Start your list with home lighting, street lighting, subways, trolley cars, automobiles, flash-



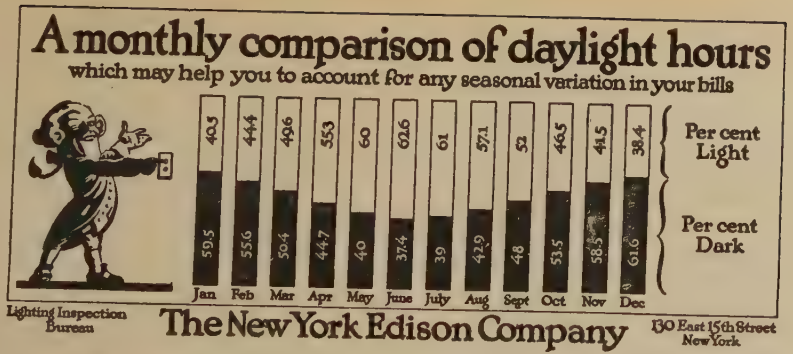
117. Use of electricity for stage lighting.

lights, Christmas trees, etc. How long can you make this list? Try it; and show the list to your teacher.

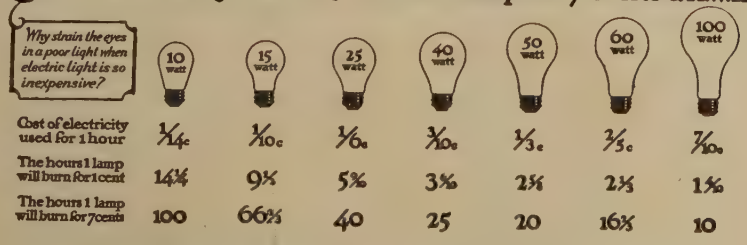
HOW MUCH DO I REMEMBER?

Is each statement true or false? If false, explain why. Write your answers on a sheet of paper so as not to mar the book.

1. Incandescent lamps were used before arc lamps were used.
2. Arc lights are poor for house lighting because they are difficult to handle and too bright.
3. One end of the filament is soldered to the side, the other to the middle of the screw-socket.
4. The black ring at the end of the screw-socket insulates one end of the filament from the other.
5. An electric lamp consists of a supported wire filament, enclosed in a glass vessel which is filled with air.



(*a*) Is your electricity bill for last May one and one-half times as large as for last January? See if your bills correspond to this chart.



(*b*) Count the lamps in your home and with this chart calculate how long they will burn for five dollars.

(*c*) Make this arc light, using pencil lead for carbons.

6. The filament wire is made of copper.
7. The light is produced by the burning of the filament wire.
8. Edison's early lamp had a tungsten filament.
9. The filament gets hot because it offers a high resistance to the flow of current.
10. A tungsten filament will evaporate more easily if the glass bulb is filled with nitrogen.
11. A bulb becomes blackened because the tungsten evaporates.
12. A nitrogen bulb lasts longer but gives off less light and consumes more current.
13. The fact that a heated filament is constantly throwing off particles is the basis of the radio tube.
14. Lamps differ in the electrical pressure required to light them. This is because they differ in resistance.
15. The wattage of a lamp tells you how much light you can get from it.
16. All lamps have the same size screw-socket.
17. In the home we use lamps of smaller wattage than we use in window displays.
18. The most common medium surrounding the filament is a vacuum.
19. There are three standard sizes of screw-sockets.
20. A lamp marked 110V–40W consumes electrical energy at the rate of 4,400 watts per hour when connected with a 110-volt source of current supply.

THINGS TO THINK ABOUT AND FIND OUT ABOUT

1. Explain the explosive sound we hear when an electric lamp is allowed to fall.
2. What is the advantage of tungsten over carbon as a substance to be used for lamp filaments?
3. Find out how lamps are manufactured.
4. How do we obtain tungsten? Find out all you can about this metal.
5. What happens when a 110-volt lamp is attached to a 220-volt electrical supply?
6. What does "C.P." stand for? How many C.P. from a 25-watt lamp?
7. When lights flicker, what is the probable cause?
8. What is meant by "heatless" light?
9. Make a list of Edison's inventions.
10. The ordinary 25-watt lamp requires a current flow of about one-quarter of an ampere. A dry cell can cause a current flow up to 30 amperes. Why can we not light an ordinary 25-watt lamp with a dry cell?
11. Find out about
    (a) arc lights; (b) mercury vapor lamps; (c) neon lamps; (d) Geissler tubes; (e) daylight lamps.
12. What is meant by "electrotherapy"?

THINGS TO DO AND MAKE

(The letters and page numbers refer to the books listed on page 18.)

1. How to use an electric lamp to test eggs.
   Book G, page 218.
2. An alarm clock which turns on the light.
   Book F, page 12.
3. A light which turns on automatically as you open the door.
   Book F, page 205.
4. A miniature lamp which can be attached to a book.
   Book F, page 42.
5. An electrical spot-light for the sewing machine.
   Book F, page 36.
6. Night-lights and lanterns.
   Book C, page 346; Book E, page 163; Book F, pages 180 and 334; Book I, pages 116 and 124.
7. A handy dark-room lamp.
   Book F, page 254; Book G, page 216.
8. How to build a reflectoscope that will project post-cards on a screen.
   Book I, page 130.
9. An electric scarf-pin.
   Book C, page 351; Book J, page 120.
10. How to make an arc lamp.
    Book F, page 346; Book G, page 210; Book J. page 127.

First incandescent-lamp factory, Menlo Park, 1880.

CHAPTER XIV

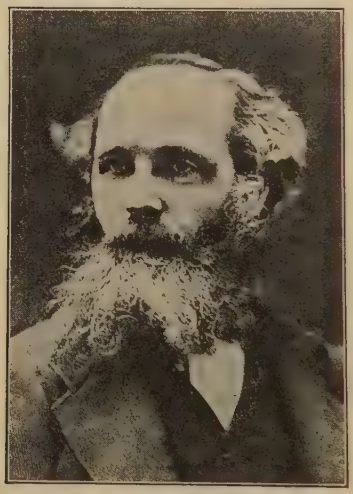
INTRODUCTION TO RADIO

Jack was a great dreamer—at least, that is what his friends all called him. His dreams were not of the weird kind that wake us in the dead of night. In fact on most nights he slept solidly and dreamlessly till morning. It was his day-dreams that gave him his reputation. At every opportunity he would tell of great plans which he had thought up. Always, his schemes would have to do with science and invention. "The next great discovery," he would begin, "will be a—" What it would be was usually never heard, because his friends would interrupt him with joking and teasing. He would then run off impatiently or try doggedly to explain his ideas.

One reason why Jack's dreams were never taken seriously was that he made it too clear that he was the great hero of them. It was always "Jack, the great inventor," and "Jack, the great explorer," until he was nick-named, "Jack, the great dreamer."

Mr. Brown, the science teacher, liked Jack for his interest in science. He would talk with Jack, show him new experiments, lend him books, and encourage him in every way. But he too felt that there was something wrong about Jack's thinking. Jack could see no connection between the work of one scientist and another. He thought of Oersted, Davy, Faraday, and Edison as men who had had great dreams which came true. That each of these men made use of the ideas of his predecessors never entered his mind. Batteries, dynamos, telephones, and radios have already been invented. What next? What was there left for Jack? It had to be something new—something entirely different. Jack spent more time in thinking about possible new inventions than he did in understanding how one idea in science leads to another.

"Who invented the radio?" asked Mr. Brown of Jack, one day. "Why, Marconi, of course," was the quick reply. "Jack, you are wrong!" said the teacher. "Marconi is a great man and he will always be known for his work in radio, but wireless waves were known before Marconi was born. Not one man, but many men were the discoverers of radio as we know it to-day. They came



119. Clerk-Maxwell.

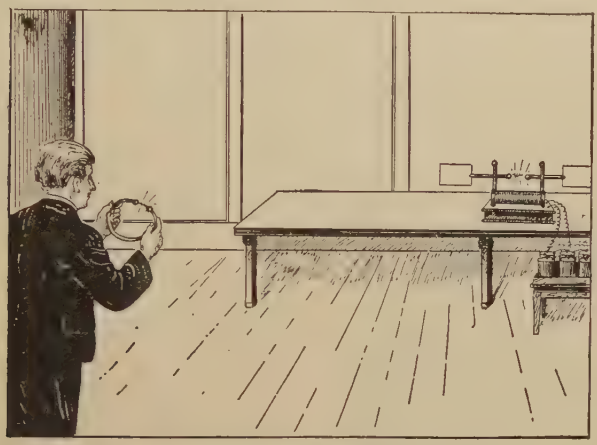
120. Heinrich Hertz.

from many lands; they worked in many different laboratories; and each one spent years in experimenting with ideas that others had originated. Let me tell you something.

"Radio was born in a mathematical equation. That doesn't mean very much to you, I suppose; but some day when you are a real scientist you will learn exactly what it does mean. Back in the days of the Civil War an Englishman named Clerk-Maxwell was studying the mysteries of light and electricity. He was not much of an experimenter. He was more interested in the mathematics of science. From some of his calculations he received the idea that there was a connection between a ray of light and electromagnets. In fact, he showed on paper that light behaved exactly like electromagnetism. You may wonder how such

a thing can be shown on paper, and yet it is so. The few men who understood what Maxwell meant hailed him as a genius. He became a famous man, though nothing came of his idea for twenty years.

"'If light rays can travel through space, why can we not also



121. Hertz discovers the Hertzian (radio) waves.

send out rays of electromagnetism?' asked the men of science. You see, Jack, here was a great idea. Men thought about it and made use of it. Soon, experimenters began to try things in the laboratory.

"Do you remember our induction coil and the lightning-like spark which it makes across the ends of the secondary coil? It was to this spark that Maxwell called attention. In a little town in Germany, in the year 1888, a young scientist was carrying on experiments with electric sparks. At one end of his laboratory he set up an induction coil. To each of the secondary terminals he fastened a square metal plate and brought a wire from one terminal to within an inch or so of the other. As he pressed a key which closed the battery circuit, a spark crackled across the gap. In his hands he held a circular loop of wire. This loop was not complete. There was a break in it about one-quarter of an inch in length. Walking to the other end of his

laboratory, he caused the induction coil to spark. To his amazement, a small spark also jumped across the break in the loop which he held in his hand. See figure 121. At last, he had found a way of sending out a ray of electromagnetism. Not only that; he had also discovered a way of detecting it. He was the first man to set up a broadcasting and receiving station, even though the distance between stations was only the length of his laboratory. Heinrich Hertz was the name of this young scientist. When one thinks of Hertz one must be grateful for his wonderful experiment and one must also regret the fact that he died at the age of only thirty-seven. If you ever run across the term, Hertzian Waves, you must know that it refers to the rays of electromagnetism which Hertz first produced and which to-day we call *radio waves.*

"Shall we continue the story of radio, Jack?" asked Mr. Brown.

"Yes, sir," replied Jack. "I suppose this is where Marconi comes in?"

"Not yet," said Mr. Brown. "Many additional experiments were performed with Hertzian Waves and at least one more discovery had to be made before Marconi comes into our story. For this next discovery let us go to France to watch Professor Branly and his experiments.

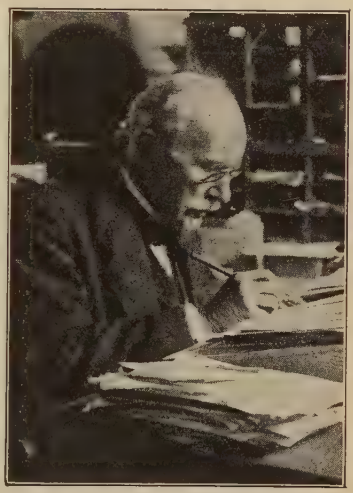
"Professor Branly was trying one day to make an electric current pass through some metal filings. The filings were packed rather loosely in a glass tube and offered a good deal of resistance to the flow of electricity. But whenever an induction coil was sparked, even when the coil was at some distance from the filings, the filings stuck together and permitted the current to flow. This was rather remarkable, because Professor Branly could now ring a bell in one room by sparking an induction coil in another room. Immediately he thought of the possibility of telegraphing without wires.

"All over the world, this experiment was now repeated. It became a scientific curiosity. The news of this wonder reached Italy, where it attracted the first radio fan—William Marconi. In 1890 Marconi was only a boy. At the age of 12, he repeated all of Hertz's and Branly's experiments. What is more impor-

tant, an ambition was born in him to use these new waves to carry messages without wires from continent to continent.

"Marconi continued his studies and his experiments. As a young man he went to England, where he attracted much attention among men of science for his brilliant mind and great experimental skill. He improved on Branly's cohering filings and succeeded in sending messages across the English Channel.

"At the age of 27, he quietly planned his first attempt to bridge the Atlantic with Hertzian Waves. He set up a sparking coil in Cornwall, England, and arranged with an assistant that he should send a signal continuously from three o'clock to six o'clock every day for several weeks. The signal agreed on was the letter 'S' in the Morse Code, which, as you may know, is three dots. Then he sailed for Newfoundland with two assistants, Mr. Kemp and Mr. Paget. He landed on the American continent on Dec. 6, 1901. In three days he was ready to begin and the first step was to raise an aerial. To do this, he sent up a huge kite with wire attached, but a blustering wind soon seized it, snapped the wire, and carried the kite out to sea. He then tried a hydrogen balloon, but it soon broke away, never to be seen again. The third attempt to raise an aerial was with another kite, and this time he was successful. The kite held his aerial at an elevation of 400 feet.



122. Branly.

"At a table in a little shack, Marconi sat waiting, with a telephone receiver at his ear. From his apparatus in the room, a wire ran out of the window to a pole and from there to the kite tossing violently in a gale. The day was raw and cold and mountainous waves dashed in to shore. Two thousand miles away Hertzian Waves were being sent out, signaling the letter, 'S,' con-

tinuously. For hours, Marconi sat quietly and calmly, listening and wondering whether his dream would come true.

"Then a look of excitement came over his face. He heard something. Faintly, but yet distinctly and unmistakably, came the three little clicks—the dots of the letter 'S.' Marconi's am-

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123. Marconi, in Newfoundland in 1901.

bition was achieved. December 12, 1901, marks the beginning of wireless telegraphy, though for two days he withheld the news from the world in order to make certain of his success."

"Did Marconi's 'wireless' now make unnecessary the Atlantic cable?" asked Jack.

"Well, not exactly," replied Mr. Brown. "Though Marconi's achievement was entirely successful, it was cheaper to send messages through wires. Even to this day the ocean cables are used extensively. However, another use for the 'wireless' was found. It happens often in scientific discovery that an invention becomes valuable in a way that the inventor never intends. In the case of 'wireless,' one of the first uses to which it was put was in providing a means of communication from ships to shore and from ship to ship. This has added greatly to the safety of ocean travel.

"About five years after Marconi's great experiment, an ocean liner was nosing her way along through a dense fog. She had 500 passengers on board and was bound for the Mediterranean. As she cautiously groped her way through the black night, she tolled her bells continuously, and at regular intervals blew a shrill siren.

"The captain was nervously pacing the deck, straining his eyes to see ahead and his ears to catch the slightest sound which might come to him from the darkness. Suddenly he stopped. Yes, he could hear faintly the fog-bell of another ship. 'Look out! Look out!' bellowed his horn. Hardly had the sound died away when an answering shriek split the fog as if to say: 'Look out yourself! I can't see!' All at once, before the captain's eyes, there loomed a huge black mass. It was the other ship, coming straight for him and coming fast. Before anything could be done there was a crash! The oncoming edge of one ship smashed into the other, crushing its hull, wrecking several staterooms and piercing to the engine room. Out went the lights. The vessels stopped. Confusion reigned on board.

"Jack Binns, the wireless operator, had turned in at about three o'clock to snatch a few hours' sleep. He was awakened by being hurled out of his bunk to the floor. One whole wall of his cabin flew into splinters and through the opening rushed the cold winter wind. His first thought was for his precious aerial wires. They were now the only link between 2,000 human beings and the outside world. The aerial was intact. Groping his way through the darkness he quickly connected his wireless set with some storage batteries. Unfortunately his batteries were not as powerful as the dynamos, which had been rendered useless by the collision; and to add to his troubles he found the sending-key lever broken. Holding the broken lever with one hand he sent out his distress message with the other. Out into the fog sped the three letters 'C. Q. D.'—'Come! Quick! Deliver!'

"Two hundred miles away the signals were heard and acknowledged. 'We are shipwrecked,' snapped Binns. 'Twenty-six miles southwest of Nantucket. Badly in need of assistance.' 'All right, old man,' came back the instant reply. With his more powerful set, the man who heard Binns's call relayed the news to

several ships known to be in the vicinity. One of them, the *Baltic*, was the nearest; she soon radioed the welcome news to Binns that she was coming post haste.

"'How are you, old man?' flashed the *Baltic* operator to Binns.

"'I'm on the job,' he replied. 'Ship sinking, but will stick to the end.'

"It took twenty-four hours for the *Baltic* to arrive, but

124. Receiving wireless messages on a ship.

throughout this time the two ships were in touch with each other, the one constantly indicating its position and the other sending words of encouragement. Barely had the passengers been removed from the wreck when she sank to a watery grave."

"Mr. Brown," said Jack, who was thrilled with the story of the rescue, "nowadays they don't use sparking coils, do they? I understand that they have vacuum tubes like the kind we use in radio sets. Who was the man who changed the Marconi wireless into the modern radio?"

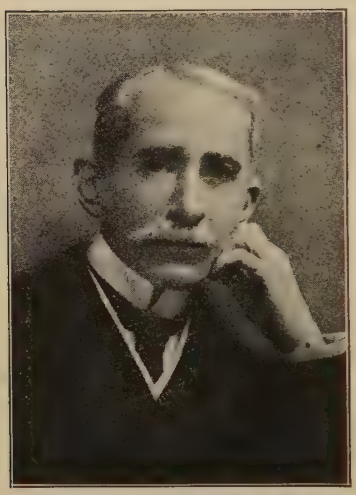
"I am glad you are interested, Jack. I hope you are beginning to see that radio was a gradual development. One idea followed another. One man experimenting with the ideas of other men found some way of improvement which was taken up by others. And so on.

"After Marconi, came Ernst Alexanderson, an American, who showed how alternating current dynamos can be used instead of sparks to send out Hertzian Waves. And then General Dunwoody discovered certain crystals which were a great improvement on Professor Branly's filings as a method of detecting these waves. But the greatest radio invention of all was the vacuum tube. Now, the idea which led to the vacuum tube was known even before Hertz performed his famous experiment. In 1883, Edison discovered a peculiarity about his electric lamp which he described to the world of science in an article. See Chapter XIII, page 146. This peculiarity became known as the Edison effect. Edison found that the space around the heated filament in an electric lamp could conduct electricity, and in one direction only. He himself made no practical use of this discovery, but Dr. Fleming, an English scientist, did. Fleming constructed a lamp which contained not only a filament but also a metal plate. Heating the filament with one battery (the A-battery) and connecting the plate with the carbon terminal of another battery (the B-battery) he found that he could detect radio waves with this device. This was a far more effective method than either Branly's filings or Dunwoody's crystal. Finally, came Lee De Forest, who changed Fleming's two-element tube into the modern three-element tube. To the filament and metal plate he added a network of wire, known as the grid, placing the latter between the filament and the plate. Edison's original lamp, which had only the two terminals belonging to the filament, now became a lamp with four terminals—two for the filament, one for the plate, and one for the grid. In this form we call it a *vacuum tube*, about which you will learn more later on."

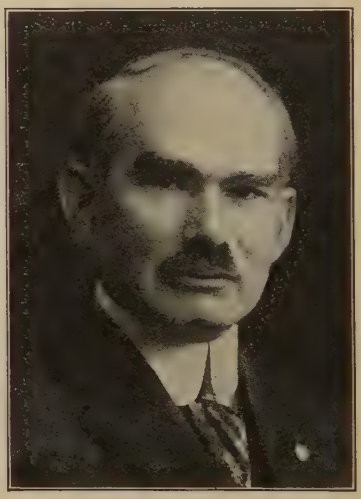
"Mr. Brown," said Jack, "I never realized how many men and how much knowledge it took to invent radio. I used to think only of Marconi—as the father of radio. Now, I see a whole assembly of scientists who are responsible for this inven-

tion. Let me see. First there was Maxwell, then Hertz, then Branly, then Marconi, then Alexanderson, Dunwoody, Edison, Fleming, and De Forest."

"That's right, Jack, but please remember also that there were



125. Fleming.



126. De Forest.

hundreds of others, each of whom added a little bit here and there. The nine great names you have mentioned were in touch with these hundreds of others and made use of their work. Not only that, they were keen students of all branches of science—particularly the science of electricity. A radio set makes use of practically every important fact which is known about magnets and the flow of electricity."

SUMMARY OF ESSENTIAL IDEAS ABOUT MAGNETS AND ELECTRICITY USEFUL FOR AN UNDERSTANDING OF RADIO

Chapter I.

(a) Magnets are bodies that attract iron and steel.
(b) Magnets may be made by induction.
(c) The magnetic force is greatest at the poles of a magnet.
(d) The magnetic force of the poles is exerted in a region near the magnet called the magnetic field.

Chapter II.

(a) An electromagnet consists of a wire coiled around a core and connected with a source of electricity.

(b) The action of an electromagnet resembles that of a bar-magnet, but may be used more advantageously.

Chapter III.

(a) In an electric bell, a vibrating strip causes a continuous "make and break" in an electrical circuit.

Chapter IV.

(a) In an electric cell, the chemical action is such that the zinc plate accumulates a great many electrons in excess of its normal number.

(b) The carbon rod, during this chemical action, loses a number of electrons equal to that which the zinc gains.

(c) Electrons tend to move from a place where they are gathered in excess to a place where there is a deficiency of electrons.

(d) A movement of electrons is an electric current.

(e) Electrons are particles of electricity.

(f) All atoms contain electrons.

(g) All molecules are made up of atoms.

(h) All matter is made up of molecules.

(i) Matter is, therefore, electrical energy.

Chapter V.

(a) A storage cell is charged by connecting its plates with a source of electricity.

(b) When properly charged, the storage cell acts like a simple cell and causes electrons to flow from one plate to the other, when a complete path is provided.

Chapter VI.

(a) Moving a magnet near a coil of wire, or a coil of wire near a magnet, induces an electric current to flow in the coil.

(b) The strength of the induced current depends upon the strength of the magnet, the number of turns of wire in the coil, and the speed of the motion.

(c) The direction in which the induced current flows changes as the direction of the motion changes.

(d) Variations in the motion of the magnet (or coil) will cause corresponding variations in the induced current.

Chapter VII.

(a) In a dynamo, an alternating current is induced in the armature coils.

Chapter VIII.

(a) Electric currents differ in direction of flow and in strength.

(b) A direct current is a flow of constant strength in one direction.
(c) A variable current is a flow of changing strength.
(d) An alternating current is a variable current which changes its direction of flow at regular intervals.
(e) Different conducting paths offer different amounts of resistance to the flow of electric current.

Chapter IX.

(a) A variable current induces a current to flow in a circuit which is near by.
(b) In an induction coil, a variable current flowing in one of its coils induces a current to flow in the other.
(c) A transformer is a kind of induction coil.

Chapter X.

(a) A telephone transmitter enables a movement due to sounds to vary the current in a circuit.
(b) A telephone receiver enables currents varying in accordance with sounds to move a disc so that it reproduces these sounds.

Chapter XI.

(a) Magnetic attraction and repulsion may cause a freely suspended electromagnet to move.

Chapter XII.

(a) Heat is produced in conductors while current is flowing in them.

Chapter XIII.

(a) In an electric lamp the filament is made to glow by the flow of electricity.
(b) A heated filament discharges electrons into the surrounding space.

HOW MUCH DO I REMEMBER?

A

Decide on the name you would use to complete each statement correctly and then arrange the statements in the order in which the events happened. Write your answers on a sheet of paper so as not to mar the book.

1. ..... substituted certain crystals for the cohering filings in the wireless set.
2. ..... was the first to send electromagnetic waves which were received on the other side of the Atlantic.
3. ..... showed that alternating current dynamos can be used to send electromagnetic waves.
4. ..... invented the three-element vacuum tube.
5. ..... showed that there was a connection between a ray of light and electromagnetism.

6. ..... discovered that the space around the heated filament of a lamp could conduct current in only one direction.
7. ..... first sent out and received rays of electromagnetism by means of sparks.
8. ..... introduced cohering filings into the wireless receiving set.
9. ..... substituted a two-element vacuum tube for coherers and crystals.

B

How would you complete the following statements?

1. Radio was discovered (by Marconi, by Edison, through the work of many men, by Hertz).
2. Radio waves are sent out by
   (a) sparks from an induction coil; (b) electromagnets; (c) Hertzian Waves.
3. Current will flow through the sounder of a wireless set when
   (a) the battery is connected; (b) the coherer filings stick together; (c) an electromagnet is moved near the set.
4. Marconi used a ..... to send out electromagnetic waves.
5. He used (a sparking coil, cohering filings, vacuum tubes) in receiving these waves.
6. In Fleming's two-element lamp the filament is connected with the ..... battery and the plate with the ..... terminal of the ..... battery.
7. The three-element vacuum tube has a ..... in addition to the filament and the plate.
8. The ordinary electric lamp has (1, 2, 3, 4) terminals.
9. The two-element lamp has (1, 2, 3, 4) terminals.
10. The three-element lamp has (1, 2, 3, 4) terminals.

THINGS TO THINK ABOUT AND FIND OUT ABOUT

(See lists at the end of Chapters XV, XVI and XVII.)

THINGS TO DO AND MAKE

(See lists of Things to Do and Make at the end of Chapters XV, XVI and XVII.)

CHAPTER XV

RADIO BROADCASTING

The famous "Roxy" (Samuel L. Rothafel) in his book on Radio Broadcasting tells the story of a deaf old man—deaf, that is, in his later years, but with some recollection of sounds heard long ago.* On putting on a radio phone this old man found that he could hear. At first he was mentally stunned; he could not speak. Sound, music, voices were penetrating a mind that had been accustomed to dead silence for years. As one looked at him one could almost see Nature providing him with a new face, the face that belongs to those who see and hear! His eyes filled, and great tears streaked down his wrinkled cheeks. It was too much for him, and the poor old soul sank into a chair quivering with emotion. "Good God!" he whispered, "I can hear it; I can hear it!" There was not one who watched him that was not moved to shed tears with him. A little later, in this same book, Roxy prints a letter which has come to him from one among his vast radio audience.

Dear Roxy:

If you can read this letter I will be glad. That you will understand it, I already know, for any man who gives of his time and talent to those whom the world has forgotten is raising a monument more enduring than granite.

I happen to be one of the victims of our late war with Germany, and as I lie on my bed with the ear-phones clamped securely in place, drinking in the remarks of the speakers, and listening to the melody of the "Gang," I feel that although for me the war will never end until I am called before the bar, yet the road is made easy and pleasant, while I wait for the summons to march. And so I thank you and your gang for the happy moments you give me, and I only wish that my thanks could take a more enduring form.

I have not long to stay. In the natural course of events I will take my

*From "Broadcasting—Its New Day," by Rothafel and Yates, Century Co., 1925.

place with those who have gone before and who have "flung the sword to those who can bear it." But while I am here I can smile and say with you, "God bless you."

One of the Walter Reed Hospital Boys,
Washington, D. C.

Radio has become a great force in our lives. Its possibilities for the future are immense. The Hertzian Waves are a magic fluid that finds its way into every nook and corner of the world. Wherever it goes it brings enjoyment, relief, and enlightenment.

Of all the inventions about which you have read in this book, radio seems to be the most difficult to understand. Because human beings find it very hard, and sometimes impossible, to move themselves quickly through space, they do not quite comprehend how a sound made in one place can be heard instantly thousands of miles away. In this and in the remaining chapters we shall try to solve this mystery by making use of the many facts about electricity which you have already learned.

Let us suppose that in the midst of a lesson, your teacher is called suddenly out of the room and you are left alone. Not knowing what else to do your classmates begin to talk to each other. It is not long, perhaps, before the room is filled with noise, and though no one in the room realizes the disturbance, it attracts your school principal. He appears in the doorway and stands for a moment, silent and stern. What happens? Every one is immediately affected. The loud din changes to a hush and quiet. The principal hasn't done anything; he has not said a word; but you all respond to his presence. Out from him as a centre there comes to all who see him a thought, an idea, a command. Because you have a mind capable of receiving such thoughts you are influenced by them when you receive them. Now, we are sure that you do not regard all this as mysterious in any way. It happens so often that you think it quite natural and ordinary. And yet, it would be just as difficult to explain this, as to explain why a radio set responds to a Hertzian Wave. A radio broadcasting station, too, is a centre of influence, of disturbance; and at some distance from it, effects will be produced. Just as there are some pupils who have minds that will not respond at all to the presence of the principal, so are there receiving sets which will not respond to certain broadcasts.

At any rate, here is the first important new idea you need in order to understand the radio, namely,

1. A disturbance at any point may produce effects at a distance

Have you ever dropped a stone into water? As the stone strikes the water it becomes the centre of a disturbance. The energy of the falling stone disturbs the water. Out from this centre in every direction, ripples begin to travel. They form circular rings which become larger and larger as they get farther away from the centre. Ten, twenty, or fifty feet away a leaf is floating motionless on the surface. When the circular ripple reaches the leaf, the latter moves. The leaf has then received some of the energy of the falling stone. See figure 127.

Clap your hands. The energy of your moving hands disturbs the air. Again you have set up a centre of disturbance. Out from this centre, in every direction, ripples begin to travel—this time in the air. They form spherical shells which become larger and larger as they get farther away from the hands. Ten, twenty, or fifty feet away there is a human ear. When the air-ripples reach the ear, the person to whom the ear belongs hears the sound. The ear has then received some of the energy of the clapped hands. See figure 128.

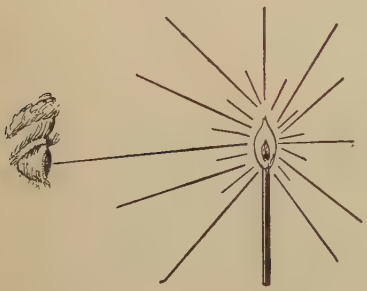
Light a match. The energy of the burning match again sets up a centre of disturbance—this time in space. Out from this centre, in every direction, ripples begin to travel—ripples of space. They form spherical shells which become larger and larger as they get farther away from the match. Ten, twenty, or fifty feet away there is a human eye. When the space-ripples reach the eye, the person to whom the eye belongs sees the light of the match. The eye has then received some of the energy of the burning match. See figure 129.

Connect up your induction coil and produce an electric spark. The energy of the electric spark is also the centre of a disturbance. In fact, it is the centre of several different kinds of disturbances. Some of the energy of the electric spark will be received by a human ear as a crackling sound. Some of it will be received by a human eye as a small lightning flash. Some of it will be re-

ceived by the human sense of touch as heat. The spark as a centre of disturbance is a broadcasting station of sound, of light, and of heat. The ear, the eye, and the sense of touch are the receiving sets which respond to these broadcasts.

127

128



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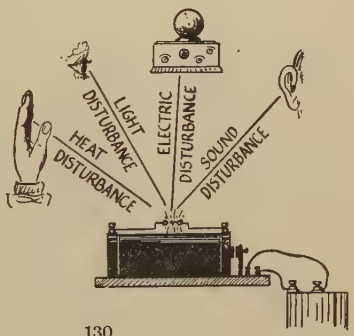


130

127. Disturbance in water.
128. Sound disturbance received by ear.
129. Light disturbance received by eye.
130. Electrical disturbance received by radio set.

But the spark is the centre of still another kind of disturbance. It is called an electrical disturbance. It is not like a sound disturbance because it passes through our ears; but we do not hear it. It is not like a light or a heat disturbance because it reaches our eyes and passes through our bodies; neither do we

see nor feel it. How, then, do we know about it? We did not know about it until Heinrich Hertz showed a way of receiving it. See page 155. Hertz invented an artificial sense really—a sense that responds to electrical disturbances just as the sense of sight responds to light disturbances and the sense of hearing to sound disturbances.

Thus a radio receiving set may be considered a new sense which has been given to mankind. At this very minute, there must be hundreds of electrical disturbances—radio waves—passing through your body. They produce no effect on your mind. Without a radio set you are not conscious of their existence. Perhaps a sinking ship is calling for help; but you know nothing of it. You are somewhat like a blind man who does not know that a person is drowning because he has no sense with which to see the light disturbances which come from the struggling figure in the water.

With a radio set, therefore, we can receive some of the energy of an electrical disturbance. See figure 130.

2. Electrical disturbances can be produced in several ways

(a) Whenever electrons are made to surge back and forth in a substance or through space, they become the centre of an electrical disturbance. That is what happens at the spark in an induction coil.

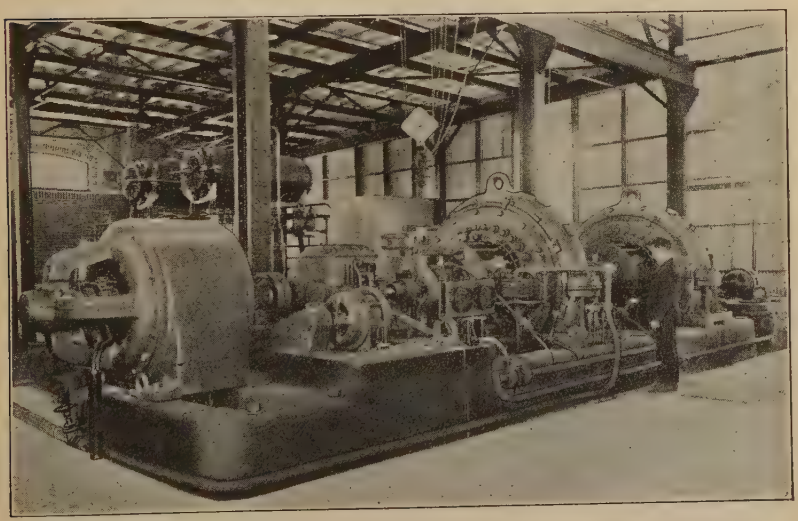
Sometimes it helps one to understand electrical things if they are compared with familiar things. Suppose, then, you stretch a rubber band and pull down the middle point. Let go. Because rubber is elastic, the middle point returns to its original position. Not only that, but it swings up and beyond its original position. This stretches it again and it swings down once more. In fact, it vibrates up and down for some time, each vibration covering a shorter and shorter distance until it comes to rest.

An electric spark acts like the rubber band described above. So many electrons are induced to flow in the secondary coil that an electrical pressure is set up great enough to break through the air-gap. Across the gap the electrons rush with great speed. So many of them are carried over in the rush that soon there

are too many on the other side. The rush then begins in the opposite direction. The electrons surge back and forth across the air-gap but in ever decreasing numbers, until there is no electrical pressure on either side of the gap. The remarkable thing is, that in one second the electrons may surge back and forth 100 million times. This is the kind of electrical disturbance which becomes the centre of radio waves.

Such waves may be used for wireless telegraphy. Marconi, you remember, used a sparking induction coil to start his waves. A long spark was a dash; a short spark was a dot. The dashes and dots stood for letters in the telegraphic code. But a wave caused by a spark is a difficult thing to alter in any way. To broadcast the sound of speech or of music, the sound vibrations must be able to introduce variations in the number of surging electrons. Since the surge of electrons in a spark quickly dies down to nothing any variations which may be introduced would also soon die out.

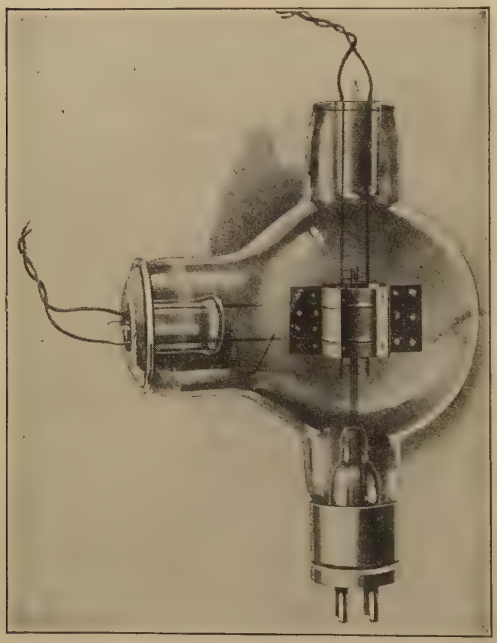
(b) Another way of getting electrons to surge back and forth is to turn an alternating current dynamo. See page 89. As the armature turns, electrons are induced to move in the armature



131. Alexanderson's alternating current dynamo for radio communication.

coils. Through one half turn they move in one direction and through the remaining half turn, in the opposite direction. Thus electrons are surging back and forth and again a centre of electrical disturbance is set up from which radio waves are sent out. Dr. Alexanderson (see figure 131) sent out radio waves in this way.

This was quite an improvement in wireless telegraphy, but the surging electrons were as hard to control here as they were in the spark.



132. A vacuum tube used in transmitting electrical disturbances.

(c) The best way to cause electrons to surge back and forth is to use a vacuum tube. In the next chapter you will find out how the vacuum tube can do this. With such a tube the surging electrons can be controlled; their numbers may be varied in any way. You can make the vibrations of speech and of music vary the surges of electrons. You can say "Hello" into a microphone, and the "Hello" vibrations will cause the surges of electrons to vary in a "Hello" manner just as in the telephone. The waves which travel out from the surging electrons will vary as do the surging electrons themselves.

3. An electrical disturbance travels outward from the centre with a speed of 186,000 miles a second

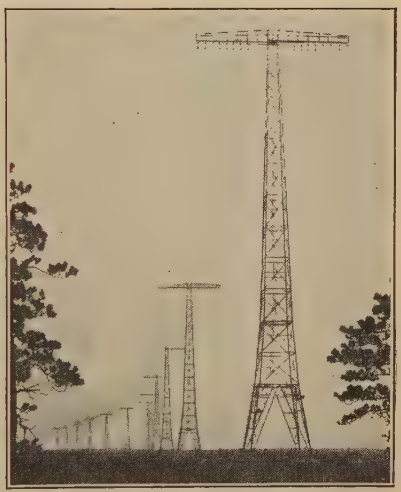
This is fast enough to travel seven times around the earth in one second.

133

133. "Radio Central"—the centre of many of our radio broadcasts.

134. The transmitting aerials at Radio Central.

135. A message from Commander Byrd by radio waves.



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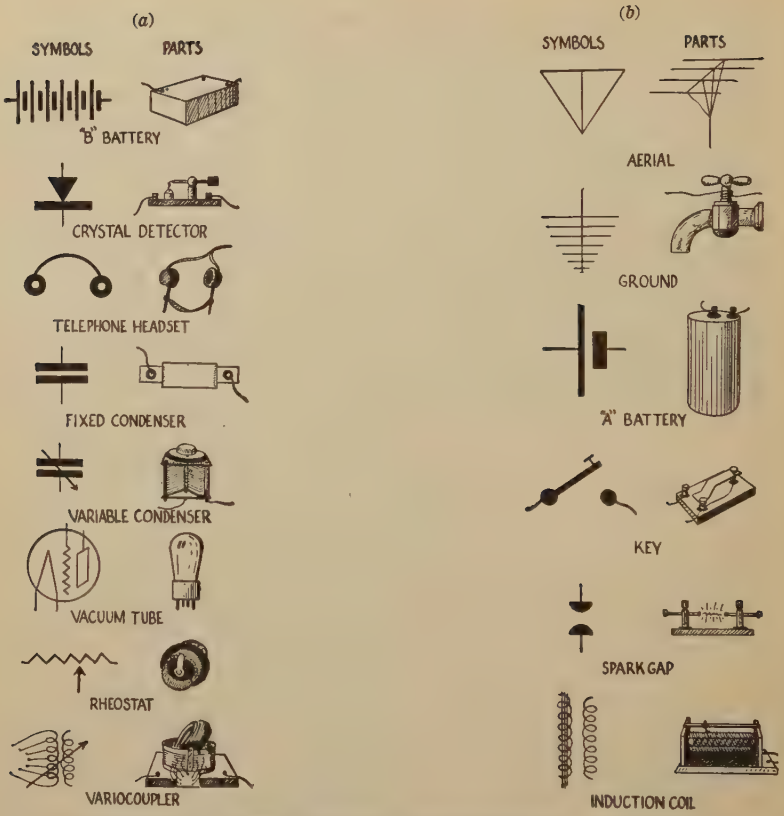
135



(*a*) Hook these up in a diagram showing a broadcasting set. Use the symbols.
(*b*) Hook these up in a diagram showing a simple receiving set. Use the symbols.

136. PROBLEM PICTURES.

HOW MUCH DO I REMEMBER?

"An electrical spark is a centre of disturbance."

1. Name several other things which may be centres of disturbances.
2. Name four types of disturbances produced by an electric spark.
3. With which of these types is radio concerned?
4. Which is caused by the surging back and forth of electrons across the air-gap of an induction coil?
5. Which of these types of disturbances can be received by our sense organs?
6. Which may pass through our bodies without being sensed?
7. What is needed in order to "receive" this type of disturbance?

8. Who made the first receiving instrument?
9. With what speed does this type of disturbance travel?
10. What else travels with this same speed?

"Electrical disturbances can be produced in several ways."

1. What three ways are considered in this chapter?
2. Which was the earliest?
3. Who first used it?
4. Which is the best method?
5. Which method was used in Marconi's experiment?
6. Which was introduced by Alexanderson?
7. Why do electrons dash across the air-gap of an induction coil?
8. Why do they rush back again in the opposite direction?
9. What may cause an electrical disturbance in space?
10. With what instrument can we best control the surging back and forth of electrons?

THINGS TO THINK ABOUT AND FIND OUT ABOUT

1. List the five most important senses which man possesses.
2. Which of man's senses is stimulated by heat energy? Which by light energy?
3. What kinds of energy stimulate the other senses?
4. If nature had provided us with a sense organ sensitive to radio energy, how would our lives be different?
5. In order to rest well when we sleep, we shut out all unpleasant light energy and sound energy, and adjust the amount of heat energy in our rooms. If we possessed a radio sense, what might we experience in an electrical storm in addition to wind, rain, lightning and thunder?
6. How does heat energy differ from light energy?
7. How does light energy differ from radio energy?
8. "In the matter of being able to receive radio energy, we are all like men born blind." In what sense is this statement true? In what sense false?
9. How does an A.C. dynamo differ from a D.C. dynamo?
10. What is the difference between a radio wave sent out by an A.C. dynamo and one sent out by a spark?
11. What is meant by "wave-length"? By "frequency"? How are the two related?
12. What is "static"? Can it be controlled? Eliminated?
13. Why is broadcasting better at night than during the day? Why better in winter than in summer?
14. What is the Heavyside Layer?
15. Find out about "wired wireless."

THINGS TO DO AND MAKE

(The letters and page numbers refer to the books listed on page 18.)

1. A spark-coil wireless transmitting set.
   Book C, page 240; Book E, page 254.
2. A coherer wireless receiving set.
   Book C, page 274; Book E, page 295.
3. How to put up an aerial.
   Book C, page 243; Book E, page 261; Book H, page 382.
4. How to build a tuning coil.
   Book C, page 352; Book E, page 271; Book H, page 387.
5. How to build a crystal detector.
   Book C, page 259; Book E, page 257; Book H, page 389.
6. A complete sending and receiving set.
   Book E, page 260.
7. How to make a variable condenser.
   Book E, page 279.
8. Wireless stunts.
   Book E, page 295.
9. How to send out electric waves.
   Book D, page 188.
10. How to make a vacuum-tube receiver.
    Book D, page 199.
11. A complete radio receiving outfit.
    Book H, page 392.

CHAPTER XVI

THE VACUUM TUBE

On Armistice Day in 1921, President Harding dedicated the tomb of the Unknown Soldier in Arlington, Virginia. His speech was heard by three audiences; one in Arlington, one in San Francisco and the third in Madison Square Garden, New York City. In all, 15,000 people heard his words at the same instant that he uttered them. In this great achievement the tiny electric currents set up by the President's voice were multiplied 3,000,000,000,000,000,000,000,000 times by vacuum tubes. This must have caused a great electrical disturbance! When some of this electrical energy reached Madison Square Garden, the amount received was not enough to produce sounds that every one could hear. Therefore vacuum tubes were again used to amplify the received electric currents 10,000,000,000 times. Both in New York and in San Francisco, the President was heard as if he had been speaking from the platform of the hall in which the people sat.

137 A loud speaker for outdoor audiences.

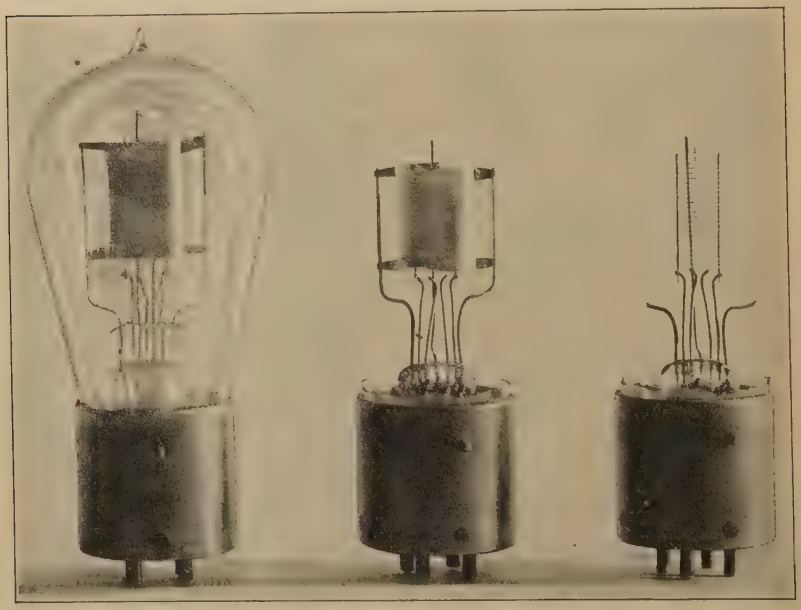
With a vacuum tube one can magnify the ticking of a watch until it sounds like a trip-hammer. Recently some one proposed that we try to broadcast to the planet Mars. Though Mars is never nearer to us than 35 million miles, the great prob-

lem is not how to make the broadcast powerful enough, but what language to use in talking to the people on Mars—if any people are there.

Let us study the vacuum tube and see how it operates to broadcast sounds in the form of electrical waves.

1. The essential parts of a vacuum tube

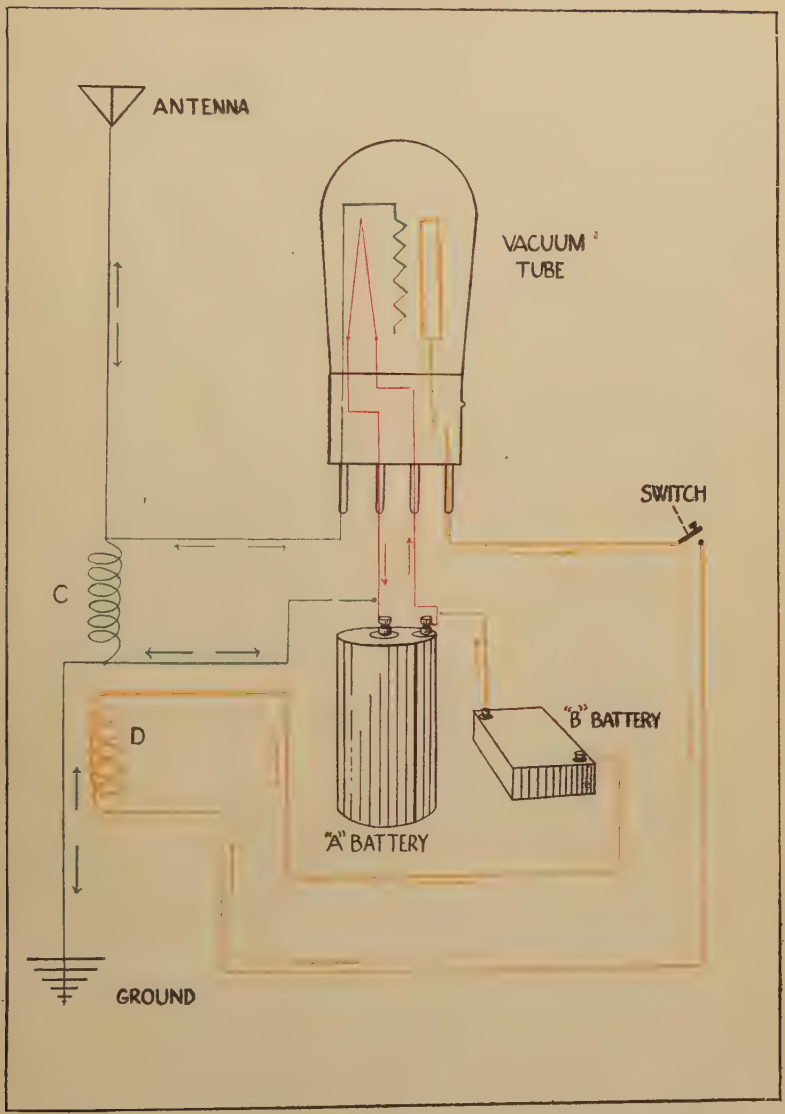
Since the vacuum tube used in broadcasting is exactly like the tubes used in your radio set (except that it is much larger),



138. Parts of a vacuum tube.

you can examine a tube taken from your set. Perhaps you have or can procure a used-up tube. You can break into this and learn more about its parts. It is rather difficult to see anything through the silvery glass.

First notice the four prongs. Two of these lead to a *filament* of tungsten wire. The third leads to a cylindrical metal *plate* which surrounds the filament. The fourth leads to a network of



139. Blackboard drawing to explain how a vacuum tube is used to broadcast a radio wave. Use colored chalk.

wire known as the *grid*, which also surrounds the filament but is inside the plate. If you break the bulb under water by the method suggested in Chapter XIII, page 144, you will discover that the space around the filament, plate, and grid is a vacuum. See figure 138 for a picture of the parts of a vacuum tube.

2. The vacuum tube operates so as to become the centre of a radio disturbance

We have reached a very important stage in our study of the radio. If you have studied and experimented with the ideas in this book, if you have read the summary at the end of Chapter XIV, you should have no trouble in understanding the next step. Read the following pages carefully, however, and do not go on to the next point if the one before it is not entirely clear.

Examine the colored diagram shown in figure 139. First there is the red circuit. This consists of an A-battery connected with the filament inside the tube. Then there is the yellow circuit. This begins with the plate inside the tube, goes around to a coil of wire, D, connects with the carbon terminal of a B-battery and goes through this battery to one side of the filament. Finally there is the green circuit. Beginning with the antenna or aerial wire, we follow this circuit through a coil, C, to the ground. At C, however, there is another branch of the circuit which goes to the grid inside the tube and also to one side of the filament.

(a) When the filament is lighted by the A-battery, it sends off electrons in every direction inside the tube. This is the famous Edison Effect about which we learned in Chapter XIII, and which we reviewed in Chapter XIV.

(b) The electrons flying off from the filament do not go in all directions for very long, because the plate is connected with the carbon terminal of the B-battery. The carbon terminal, as you know from Chapter IV, is lacking in electrons. It is therefore constantly taking electrons from the plate.

(c) Because the plate is lacking in electrons, the electrons flying from the filament rush to the plate. Electrons always go from a place where they are gathered in excess to a place where they are lacking. (Chapter IV.)

(d) Thus the only gap in the yellow circuit, or plate circuit

as we will call it, is bridged by the moving electrons. A current is now flowing in the plate circuit which must necessarily go through the coil D.

(e) As the current begins to flow in coil D, it induces a current to flow in the near-by coil C. This is exactly like the action of any induction coil.

(f) Now, where do the electrons which are induced to flow into coil C come from? They must come from the aerial and the grid and are crowded into the ground.

(g) The grid has therefore lost electrons. It is like the plate. It will now help the plate to draw the flow of electrons from the filament. Since the grid is an open network, very few of the electrons from the filament will strike the grid. Most of them will rush through to the plate, thereby increasing the current in coil D. Increasing the flow of current in D means a still greater induction in coil C. This draws still more electrons out of the grid, so that the grid can give additional help to the plate. This continues until the space between filament and plate is so crowded with electrons rushing to the plate that there is room for no more.

(h) So soon as this point is reached, the current in coil D stops increasing. With the current constant no further induction can take place in coil C. Now, all this time the electrons have been crowded into the ground; but with no induction in coil C, they begin to rush back from the ground into the aerial and grid, where they are lacking. In the grand rush from ground to aerial and grid, a great many extra electrons are swept along, so that soon the grid and aerial have more than their normal number.

(i) The grid now opposes rather than helps the drawing power of the plate, until the filament electrons can not reach the plate at all. At this point the excess electrons in aerial and grid must rush down again to the ground. Then the process is begun all over again.

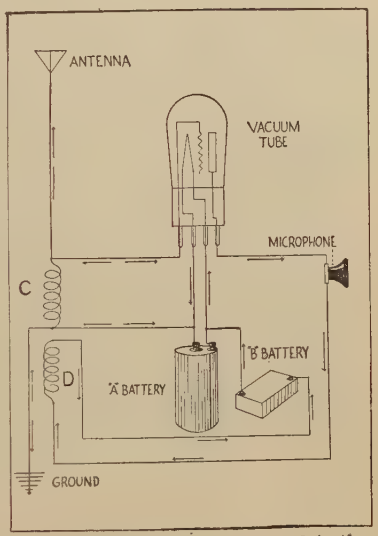
(j) The important result of all this is that we have caused a constant surge of electrons from aerial and grid to the ground and back.

(k) *The grid circuit is then the centre of an electrical disturbance from which there travels a radio wave in all directions.*

3. The radio disturbance may be varied in accordance with the variations in sounds

Look at the diagram, figure 140. It is an exact reproduction of the diagram in figure 139, except that one thing has been added —a telephone transmitter, or microphone. This has been inserted in the plate circuit and is of the same type as the one which we studied in Chapter X, page 113.

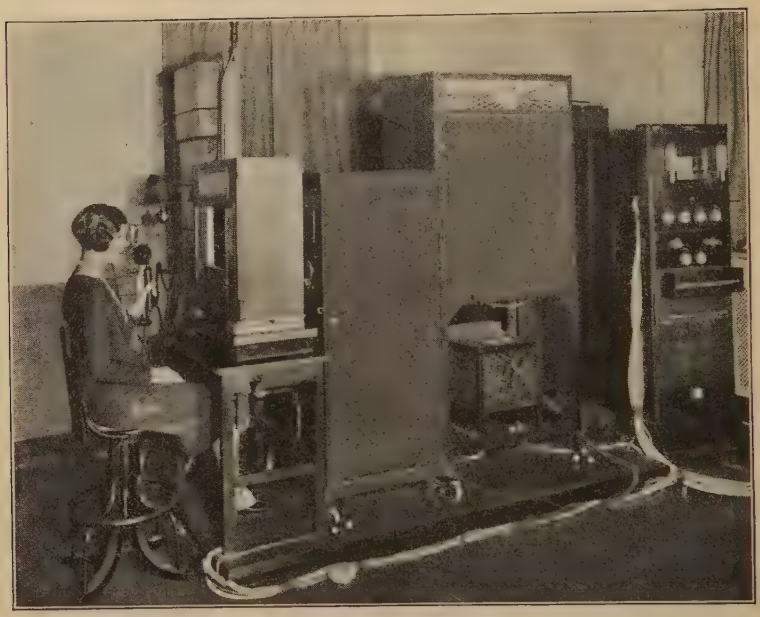
Introducing the transmitter does not change anything. The electrons are surging back and forth in the grid circuit and out from the aerial go radio waves. These waves are of constant strength, because the surge of electrons is constant. Suppose that you say "Hello" into the transmitter or microphone. The vibrations of this sound will



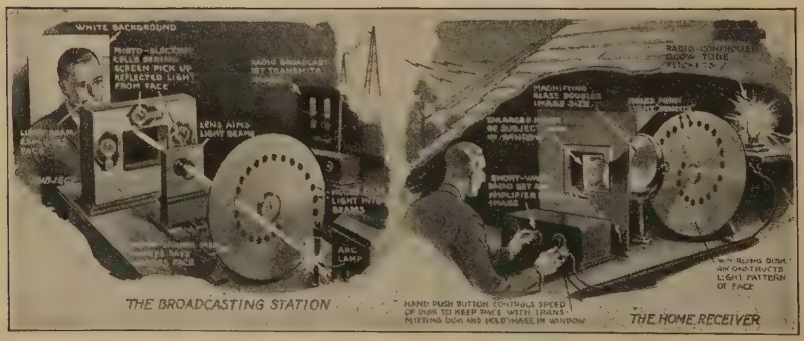
140. Blackboard drawing to explain the broadcasting of speech.

141. The modern radio microphone.

cause the disc to vibrate in a "Hello" manner. The carbon granules will be compressed in a "Hello" manner. In fact, the current in the plate circuit will be caused to vary in a "Hello" manner. Whatever these variations are, they will flow through the coil D. Corresponding variations will therefore be induced in the current flowing in coil C. But coil C is part of the grid circuit. Thus, the surging electrons in the grid circuit now surge



(*a*) Television apparatus. Where are the vacuum tubes?


WHITE BACKGROUND
LENS AIMS LIGHT BEAMS
ARC LAMP
THE BROADCASTING STATION
HAND PUSH BUTTON CONTROLS SPEED OF DISK TO KEEP FACE WITH FRAME
THE HOME RECEIVER

(*b*) How are vacuum tubes used in this television apparatus? Can you explain how this works?

with variations. They surge in a "Hello" manner. The radio wave which now travels out from the antenna is no longer a smooth one, but a varying one. Radio engineers call it a *modulated wave*. It varies in accordance with the word "Hello." See figure 141.

HOW MUCH DO I REMEMBER?

Below are five statements of things that happen when a vacuum tube is in operation. Arrange these statements in the exact order in which they happen.

a. The filament electrons rush in great numbers to the plate.
b. The A-battery makes the filament red hot.
c. The carbon terminal of the B-battery is lacking in electrons.
d. The plate is connected with the carbon terminal of the B-battery.
e. The heated filament sends off electrons in every direction.

Arrange the following in the same way:

a. Electrons flow from aerial and grid to the ground.
b. Variable current flowing in the plate circuit induces current to flow in the grid circuit.
c. A current of electricity begins to flow in the plate circuit.
d. The grid helps the plate to draw electrons toward the plate.
e. The grid is lacking in electrons.

Also arrange the following in the proper order:

a. The grid gives the plate still more help in attracting electrons.
b. There is no further induction of current in the grid circuit.
c. An increasing current flow in the plate circuit causes an increasing flow in the grid circuit.
d. The flow in the plate circuit stops increasing.
e. The space between filament and plate becomes extremely crowded with electrons.

Finally, arrange the following statements in the proper order:

a. The grid now opposes the attracting force of the plate.
b. The aerial and grid electrons flow down again to the ground.
c. There is a rush of electrons from ground to grid.
d. The shuttling electrons in the grid circuit become the centre of an electrical disturbance.
e. The flow in the plate circuit becomes practically zero.

THINGS TO THINK ABOUT AND FIND OUT ABOUT

1. Why is a vacuum tube called a "triode"?
2. What is a "diode"?
3. The vacuum tube was first used in telephone transmission. Find out what its use was.
4. What is meant by "carrier-wave"?
5. What is meant by a "modulated" wave?
6. What is meant by the statement, "This tube uses the raw 110-volt A.C."?
7. "Match your tubes," said the dealer, "and you will get better results." Explain what the dealer meant and find out why tubes need to be "matched."
8. Why does a C-battery help a tube to function?
9. Why is a "grid-leak" necessary?
10. What is the purpose of the metallic coating on the inside surface of a tube?
11. How does a broadcasting tube differ from a receiving tube?
12. How does a rectifier tube differ from a receiving tube?
13. Explain why, in most of the all-electric sets, there is a delay of a few seconds after snapping on the set, before you hear anything.
14. Just what is a "power" tube?
15. One type of tube, recently developed, has five instead of four prongs. Find out what the fifth prong is for.

THINGS TO DO AND MAKE

(The letters and page numbers refer to the books listed on page 18.)

1. How to make old vacuum tubes into Geissler glow lamps.
   Book F, page 401.
2. Using a vacuum tube in a transmitting set.
   Book D, page 197.

(The following projects refer to books listed on page 199 in the Appendix.)

3. How to treat vacuum tubes.
   Book 3, page 178.
4. Simple vacuum tube connections.
   Book 3, page 161.
5. A vacuum tube as a rectifier.
   Book 3, page 193; book 4, page 269.
6. A vacuum tube receiving set.
   Book 4, page 108.
7. A vacuum tube telegraph transmitting set.
   Book 4, pages 11 and 274.

CHAPTER XVII

RADIO RECEPTION

The other night I went to see a movie in one of New York's famous palaces of the screen drama. It was a relief to step from the crowded, noisy street to the quiet, dimly lighted lobby of the theatre. The price of an admission took me from the bright glare of Broadway into a hall of oriental splendor. There were thick carpets to walk on, beautiful paintings and statuary to look at, and courteous attendants to guide me carefully to a seat. I sank into the soft, luxurious cushion and relaxed.

For a few moments I did not look at the screen, but rather at the exquisite spectacle around me. Even more beautiful than the lobby was the hall in which I found myself. It was like the palace of a king—a palace which I had always thought existed only in fairy-land.

Though thousands of people were all around me, the air was fresh and just warm enough. The light was subdued so as not to interfere with the screen; yet it was sufficient to reveal the charm of the interior. Soft music from the organ and symphony orchestra filled the hall, and as the screen artistically announced the next feature the musicians slowly sank from view.

The screen now claimed my attention. With my body in the utmost physical comfort, my mind was carried to a frozen, deserted, and barren part of the earth. I could see a long team of arctic dogs dragging a heavily laden sledge over deep snows and ice. A close-up of the animals showed them straining every muscle and panting for breath. The human beings with them showed on their faces the strain of long months of hardships, hunger, and freezing temperatures. They were a party of explorers—seeking unknown regions of the earth. The scene was an introduction to a "news-reel" and was followed by a view of the departure from civilization of Byrd's expedition to the Antarctic.

On the *City of New York* (Byrd's ship), as she steamed away, there were two things which no similar expedition ever had taken along in such great quantity. These were airplanes and radios. On the screen now appeared a gentleman who announced himself as a representative of the *New York Times*. His words resounded through the hall as if he were actually present in the theatre. "Commander Byrd," he said, "has now been in the Antarctic for some time. By special arrangement with our paper, he keeps in daily touch with us by radio. Right here, in the heart of New York City, we receive each day the messages he sends, though he is ten thousand miles away. We shall now give you an opportunity of listening to one of these messages."

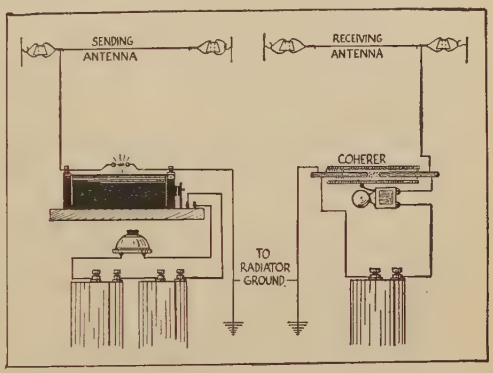
There then appeared on the screen the radio room to which the speaker referred. A wireless operator sat before his apparatus with a head-set fastened to his ears. Turning to the audience he removed the phones and held them so as to face us. Beyond a doubt, we could hear the signals. A continuous series of dots and dashes rang out through the hall. Though I could not understand the dots and dashes, I had been able to read the full account of Byrd's latest adventures in the newspaper that morning. Here I was, in the comfort of a New York theatre, listening to a man ten thousand miles away, who was telling of an encounter with ferocious "killer-whales," of a temperature lower than zero, and of sights and scenes which had never met the eye of a human being before.

The news-reel soon went on to other things, and in a few minutes gave way to an exciting story; but the outstanding event for me was hearing Byrd's message. I kept thinking of it for days. Five great inventions had been combined to give me a thrill: the telegraph, the telephone, the radio, the motion picture, and the phonograph. The most startling achievement, of course, was the receiving of the signals at such a distance. I made a firm resolve to learn all I could about the modern radio receiving set.

1. Radio waves may be received with a coherer receiving set

Would you like to send and receive radio messages with a set such as Marconi used? Examine carefully the diagram shown

in figure 143. You can set up the sending set at one end of your science room and the receiving set at the opposite end. Note how the aerial wires are insulated from the walls with rubber stoppers. The sending and receiving aerials should be of the same kind of wire and of the same length. For the ground connections use the radiator pipes. File off the point where you make the connection. In the sending outfit you use an induction coil connected with as many cells as you need to obtain an eighth-of-an-inch spark across the secondary terminals. For the key use a push button or a telegraph key. The receiving set is an electric bell which rings when current flows through it from the cell. You will notice that the current from the cell can reach the bell only through the coherer. Now, what is the coherer? It is a glass tube into which two metal rods have been inserted from either end. The rods do not touch inside. The outer end of one rod is connected with the aerial and the outer end of the other rod is connected with the ground. The space between the rods, inside the glass tube, is filled with filings of nickel and silver. You can make such filings by sacrificing a nickel and a dime.



143. A spark-coil sending set and a coherer receiving set. Try this out in your classroom.

When you press the key of the sending set, a spark jumps across the air-gap. Radio waves are sent out in all directions. When these waves sweep by the receiving aerial, they induce a current to flow from the aerial, through the coherer, to the ground. This current, which is alternating, causes the filings to stick together (cohere). Thus the gap between the rods is closed and the current from the cell can now flow through the bell to ring it.

In order to be successful with this radio receiving set, it is necessary to adjust the rods carefully, so that before the signal is broadcast they are as close as possible without ringing the bell.

Of course, once the filings stick together, they will stay stuck; and the bell will continue to ring after the signal has ceased. To *de-cohere* the coherer and get it ready for the next signal, arrange the bell so that its clapper will strike the glass tube as well as the gong. See figure 144. This was the ingenious scheme devised by Marconi.

After you have learned to adjust this coherer receiving set, try it out at home on a real roof-aerial. **You can not tune in on** music and speech, **but you** may be able to tune in on so-called "code messages." To change the length of the aerial, for tuning purposes, introduce the loading coil into the circuit. See figure 145.

2. Radio waves may be received with a crystal receiving set

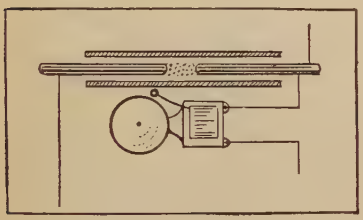
Having received messages in the manner of Marconi, you may be interested in receiving messages by the improved method of Dunwoody—the man who invented the crystal set. In figure 146 you see the new receiving "hook-up." The sending set is the same you used before. In making contact with the crystal, be sure that the little coiled wire (the "cat's-whisker") which rests against it, touches a sensitive spot. You find the sensitive spot on the crystal by trying various spots, as you listen in the telephone receiver for the loudest signals. This set, when you have adjusted it, will enable you to receive music and speech.

The explanation of how a crystal set operates is very interesting. As the radio wave sweeps by the receiving aerial, it induces a current to flow from the aerial through the entire circuit to the ground. From the preceding chapter we know that this current must be an alternating current. Also, since the wave has variations in it corresponding to the sounds broadcast, the current induced in the aerial-to-ground circuit must also be variable in accordance with the broadcast sounds.

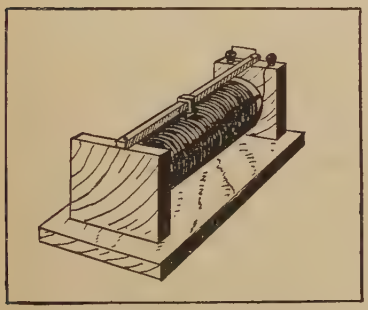
Now, the alternations in the direction of flow are very rapid —so rapid, in fact, that the disc in the telephone receiver can not

possibly move back and forth to keep pace with the changing direction of flow. Therefore, it would do no good to let these currents flow directly through the telephone receiver; since the disc would stand still. You would hear nothing.

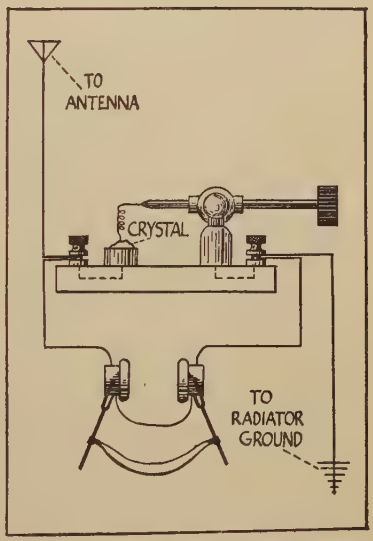
However, the crystal is inserted in the circuit. Now, a crystal possesses the ability to let current through in only one direction. It is like a one-way street. If the telephone receiver is connected



144. The coherer.



145. "Loading" coil for "tuning in."



146. "Hook-up" for a simple crystal set.

with the aerial through the crystal, currents are able to flow through it in only *one* direction. The disc is then pulled over. Furthermore, any variation in the strength of the current pulls it nearer the magnet or pushes it away. These pulls and pushes, depending as they do on the varying strength of the induced current, cause a movement of the disc back and forth. Thus, the disc vibrates and reproduces a sound. The sound produced depends on the variations in the induced current, which in turn depend on the variations in the radio wave. Since the latter

variations are in accordance with the speech and music at the broadcasting studio, the disc in the telephone reproduces the original speech or music.

3. Radio waves may be received with a vacuum tube

In figure 147 you see how to hook up a one-tube radio set. The different parts are purposely separated so as to make the connections clear. Ordinarily the parts are set closely together on a panel.

Examining this diagram you will find that it resembles very closely the one studied in Chapter XVI. The red-colored filament circuit is an old friend. In this circuit, the cell lights the filament, whereupon electrons are discharged from the filament in all directions. Now look at the yellow-colored plate circuit. This is practically the same as in the broadcasting diagram you have already studied—with one exception. Instead of a telephone transmitter, there is now a telephone receiver. Since the plate is connected with the carbon terminal of the B-battery, it has electrons removed from it by the carbon terminal. Hence the discharged filament electrons now rush to the plate and flow through the telephone receiver to the carbon terminal. This flow is a steady one, so that if you listen at the telephone receiver you can hear nothing.

Finally, look at the green-colored grid circuit. This consists of a coil, D, very close to another coil, C. Coil C connects the aerial with the ground.

When you receive sounds that are broadcast, this is what happens: as the radio wave sweeps by the aerial, it induces a current to flow in the aerial circuit. This is in the usual manner. The flow is an alternating one and varies in strength in accordance with the variations in the radio wave.

With a variable current flowing in coil C, a correspondingly variable current is induced in coil D.

Let us study the current which now flows in coil C, which is part of the grid circuit. First, electrons flow out of the grid and through the coil D, and then reverse their direction, crowding into the grid.

Therefore, the grid sometimes has electrons in excess and at other times is lacking in electrons. When it lacks electrons, it helps the plate to draw into the plate circuit the discharged filament electrons. When it has electrons in excess, it retards the flow of discharged filament electrons.

Thus variations are set up in the plate circuit. Since the telephone receiver is part of the plate circuit, these variations cause the disc to be pulled nearer to the magnet or pushed further away. That means that the disc vibrates and produces a sound.

What sound does it produce? A sound which corresponds to variations in the flow of current. Since those variations were caused originally by variations in the radio wave, the sounds are the same as the ones spoken into the microphone at the broadcasting studio.

4. Radio waves are received with maximum effects when the receiving circuit is tuned to the sending circuit

When a radio wave sweeps by an aerial, a current is induced to flow in the aerial circuit. But how strong is this current? Sometimes, it may be so weak that no effects are produced in the telephone receiver. Then you hear nothing. But if the receiving circuit is similar in size, shape, and arrangement to the sending circuit, the induced currents are the strongest possible under the circumstances.

That is why every radio receiving set is provided with variable coils and variable condensers. When you turn the dials you are changing the size, shape, and arrangement of the receiving circuit. When you hit on a size, shape, and arrangement similar to the broadcasting circuit you are greeted by a burst of music. You have "tuned in." Since different broadcasting stations are compelled by law to broadcast always with the same circuit, you soon learn where to adjust the dials on the receiving set so as to tune in the different stations.

It may help you to understand this process of "tuning in" if your teacher performs the following experiment with two tuning forks.

These tuning forks are almost exactly alike in size, shape,

mounting, arrangement, etc. One of them, however, has a little metal rider on one of its prongs. Strike one fork sharply with a rubber stopper fastened to the end of a stick. The fork gives out a sound. Stop the sound by touching the fork with your hand. Does the second tuning fork give out a sound? Listen carefully. If not, move up the rider a little bit and try again. Eventually you find the place to slide the rider to, so that the second fork sounds when you strike the first. You see, the first fork when struck is broadcasting air waves. When these waves sweep by the second fork, removed from the first perhaps by two or three feet, they make the second fork vibrate too. But these induced vibrations are at their maximum only if the rider is in the correct position, that is, if the second fork is in tune with the first.

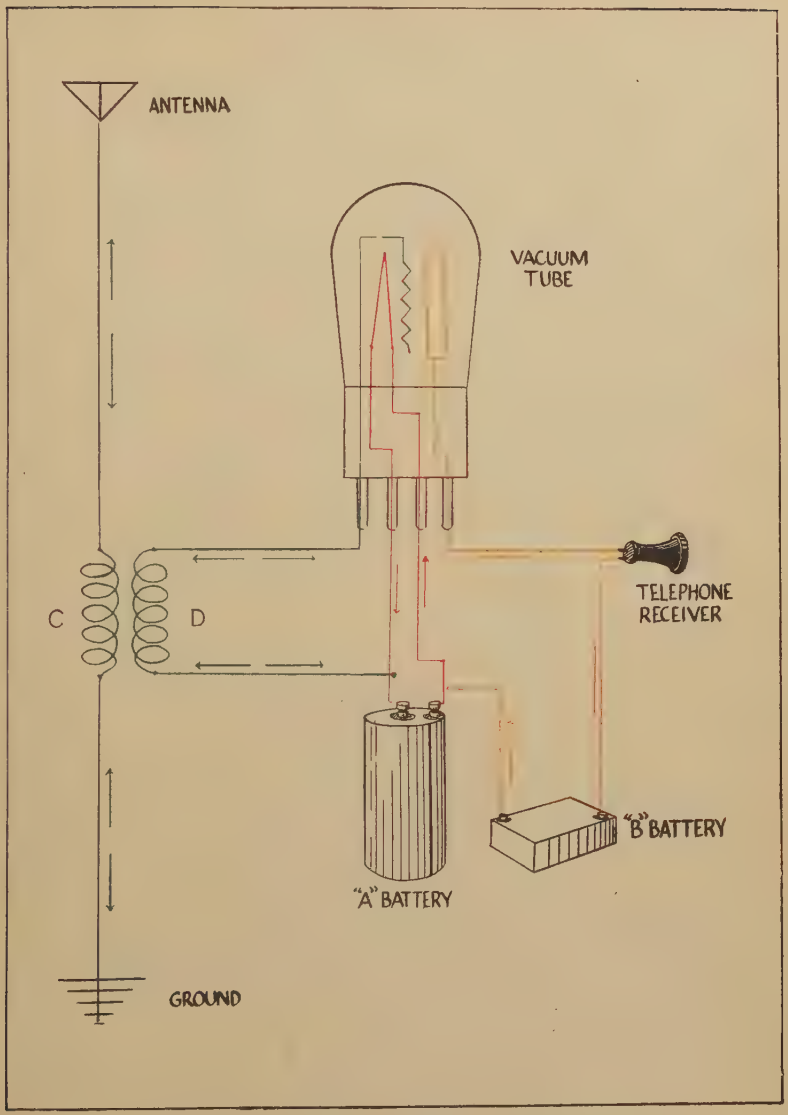
5. A second vacuum tube may be used to amplify the effects produced by the first

Study once again the diagram in figure 147 and the explanation of it on pages 190 and 191. Putting your ear next to the disc in the telephone receiver enables you to hear the broadcast of the station to which you are tuned in.

But suppose **it is not loud enough**. Suppose you wish to fill the room with sound. Substituting a loud speaker for the telephone receiver does not help much. A loud speaker is, after all, only a telephone receiver with a horn. What you need is a large amount of current in the plate circuit—an amount large enough to move a large iron disc; or, as in the case of the cone and dynamic speakers, an amount of current large enough to magnetize a coil of wire and make it move, together with the cone to which it is attached.

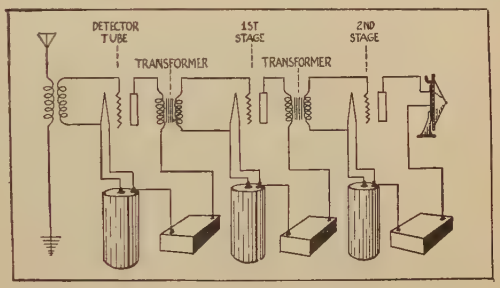
To increase the amount of current flowing in the plate circuit use a transformer and another tube—usually two transformers and two tubes. This is called "two stages of audio amplification."

Look at figure 148. In tube No. 1, called the "detector," we have the usual hook-up, except that the telephone receiver is missing. Instead, there is the primary coil of a transformer.



147. Blackboard drawing to explain a simple vacuum tube receiving set. Use colored chalk.

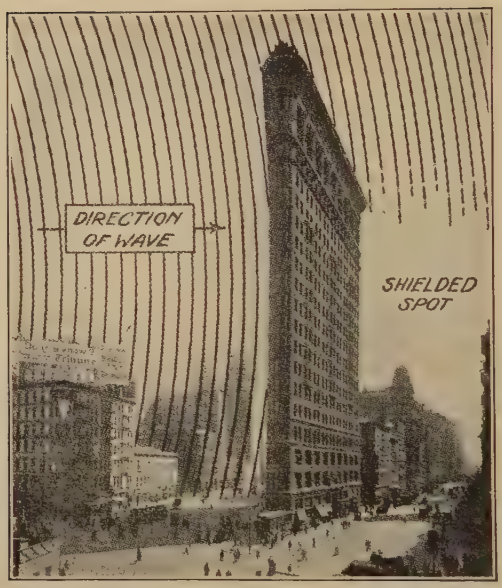
Since the secondary coil has twice or three times as many turns as the primary coil (see Chapter VIII), the variable currents in the primary induce a more forceful and correspondingly varying current in the secondary. This current is now brought to the grid of the next tube, where it causes corresponding and more forceful variations in the plate circuit of that tube. There too, is a transformer which repeats the process and brings to the grid of the third tube a still more forceful current. In the plate circuit of this last tube is now placed a loud speaker. The variable currents, in the usual manner, change into the sounds carried by the radio wave. This time they are loud enough to be heard all over the room.*



148. How tubes are used to amplify radio reception.

Of course, modern receiving sets use more than three tubes. The number often goes to eight and nine. In general, the action is as described above, though there are some differences, which cannot be discussed here. If you understand what was described in the last few chapters you are in a good position to learn more. Study your set at home. Read the Radio Sections in the newspapers and magazines. Get from the library some of the books listed on page 199 in the Appendix. In these ways, you can become a radio expert.

*In the diagram we show a separate A-battery and separate B-battery for each tube. This is done for the sake of simplifying the connections. In a real set, only one A-battery and one B-battery are used for all the tubes.



(*a*) How do the tall buildings in your neighborhood affect radio reception?

(*b*) How many stations were hooked up in the "network" over which President Hoover's inauguration was broadcast?

149. PROBLEM PICTURES.

HOW MUCH DO I REMEMBER?

A

What word or words would you use to complete the sentences below so as to make them true statements? Write your answers on a sheet of paper so as not to mar the book.

1. The aerial wire of a radio set is ..... from the wall.
2. ..... can be used for ground connections.
3. A coherer set can receive electrical disturbances produced by (sparks, dynamos, vacuum tubes).
4. The receiver in a coherer set is a (telegraph sounder, bell, telephone receiver, loud speaker).
5. The coherer is .....
6. Electrical disturbances induce a current in the aerial which causes the filings of the coherer to ... .
7. Three types of receiving sets are .....
8. The crystal set was invented by .....
9. The ..... is a device for permitting the current to flow in only one direction.
10. In a vacuum tube receiving set, the ..... battery heats the filament of the tube. The filament sends out ..... in all directions.
11. A radio transformer illustrates the principle of .....
12. A receiving set is tuned to a sending set by means of .....
13. A second vacuum tube may be used to ..... the effects of the first.
14. Two stages of audio frequency require ..... vacuum tubes.
15. The tube which receives the aerial current directly on its grid is called the ..... tube.

B

Pick out the false statements and explain why they are false:

1. The bell is used in the coherer set because besides giving the signal it serves to de-cohere the instrument and prepare it for the next signal.
2. The telegraph or loud-speaker might be used in this set.
3. The coherer is connected with the aerial and the ground.
4. The bell of the coherer set does not ring continuously because its circuit is broken by a push button.
5. The nickel and silver filings conduct the current across the gap between the metal rods of the coherer at all times.
6. The coherer must be tapped before it can receive a second signal.
7. Music can be received with a coherer set.
8. Music can be received with a crystal set.
9. Contact with the crystal is made when the "cat's whisker" touches any spot on its surface.

10. The variations in the current which is induced in the aerial are just the kind which can operate a telephone receiver.
11. The parts of a vacuum tube receiving set are different from those of a transmitting set.
12. A radio wave induces the strongest possible current in an aerial only when the aerial circuit is tuned to the sending circuit.
13. A broadcasting station is constantly changing its circuit with variable coils and condensers.
14. The variable current in the plate circuit of the detector tube may be sent through a transformer for amplification.
15. In order to amplify the sound of a one-tube set, another tube is introduced in place of the telephone receiver.

THINGS TO THINK ABOUT AND FIND OUT ABOUT

1. What cyrstals can be used in radio receiving sets?
2. What is a "Radio Net-Work"?
3. What kind of an aerial has a submerged submarine when it tunes in to broadcast?
4. What kind of ground connection has a flying airplane when it tunes in to broadcast?
5. Find out about the following improvements in radio reception:
   (a) Dynamic Speaker; (b) Orthophonic Horn; (c) A.C. Tubes (d) Power Tubes; (e) Battery Eliminators.
6. Identify the following radio terms:
   Reflex, Regenerate, Audio-Frequency, Rheostat, Transformer, Condenser, Variometer, Neutralizing Condenser, Vernier, Cone-Speaker, Heterodyne, Interference, Fading, Trickle-Charger, Selectivity, Wave-Band, Loop, Variocoupler, Fixed Condenser, Detector, Power Unit, C-Battery, Two-Stage, Body Capacity.
7. What standards would you adopt in purchasing a radio receiving set?
8. How has radio affected the phonograph?
9. What is meant by one-dial tuning? By automatic tuning?
10. What is the effect of skyscrapers on radio reception?
11. What is the Radio Commission?
12. How are pictures transmitted by radio?
13. What is meant by the "death" ray?
14. What is meant by "radio transmission of power"?
15. Find out about the "radio compass."

THINGS TO DO AND MAKE

(The letters and page numbers refer to the books listed on page 18.)

1. An adjustable stand for crystal detectors.
   Book F, pages 327 and 401.
2. The Haversack wireless crystal set.
   Book I, page 155.

3. An amateur wireless set.
   Book I, page 162.
4. A simple wireless telephone for transmitting and receiving.
   Book C, page 281.
5. How to make your own lightning arrester.
   Book C, page 112.
6. A simple one-tube radio set.
   Book F, page 410.
7. Other simple receiving sets.
   Book C, pages 241 and 272; Book D, page 189; Book H, page 379.
8. How to construct radio receiving apparatus.
   Book C, page 243; Book E, page 261.

APPENDIX

A LIBRARY OF SUPPLEMENTARY BOOKS FOR THE SCIENCE CLASSROOM

FIVE SETS OF REFERENCE BOOKS

1. The Book of Popular Science—15 volumes (The Grolier Society).
2. Compton's Pictured Encyclopedia—10 volumes (F. E. Compton and Co.).
3. The Wonderbook of Knowledge—one volume (J. C. Winston Co.).
4. Popular History of American Invention—2 volumes (Charles Scribner's Sons).
5. Pocket Guide to Science—one volume (Popular Science Monthly).

FOUR HELPFUL TEXTBOOKS ON ELECTRICITY

1. Electricity and Magnetism, by Jackson (Macmillan).
2. Essentials of Electricity, by Timbie (Wiley).
3. Everyday Electricity, by Wade (Little, Brown).
4. Everyday Electricity, by Lunt (Macmillan).

TWENTY-FIVE SUPPLEMENTARY REFERENCE BOOKS FOR THIS GRADE

1. Adams—Harper's Electricity Book for Boys (Harper and Bros.).
2. Clarke & Small—Boy's Book of Physics (E. P. Dutton & Co.).
3. Collins—Book of Magic (D. Appleton & Co.).
4. Collins—Inventing for Boys (Thomas Nelson & Sons).
5. Darrow—Boys' Own Book of Invention (Macmillan).
6. Darrow—Boys' Own Book of Science (Macmillan).
7. Fournier—Wonders of Physical Science (Macmillan).
8. Gibson—Romance of Modern Electricity (Lippincott).
9. Gibson—What Is Electricity? (Lippincott).
10. Gilbert—Fun With Magnetism, etc. (A. C. Gilbert Co.).
11. Goode—Magical Experiments (David McKay).
12. Houston—Wonderbook of Magnetism (Stokes).
13. McCabe—Marvels of Modern Physics (Putnam).
14. McDougal—Wonders of Electricity (Pitman).
15. McKay—Easy Experiments in Electrical Science (Oxford University Press).
16. Onken—How to Understand Electrical Work (Harper and Bros.).

17. Schaefer—Harper's Beginning Electricity (Harper and Bros.).
18. Seaver—The American Boy's Book of Electricity (David McKay).
19. Small—Boys' Book of Electricity (E. P. Dutton & Co.).
20. Talbot—All About Invention and Discovery (Funk and Wagnalls).
21. Williams—How It Is Done (Thomas Nelson & Sons).
22. Williams—How It Works (Thomas Nelson & Sons).
23. Williams—Things To Make (Thomas Nelson & Sons).
24. Williams—Things Worth Making (Thomas Nelson & Sons).
25. Woodhull—Electricity and its Everyday Uses (Doubleday, Doran).

TWENTY SCIENCE BIOGRAPHIES

1. Bachman—Great Inventors and Their Inventions (American Book Company).
2. Bolton—Famous Men of Science (Crowell).
3. Brooks—Benjamin Franklin (Lothrop, Lee and Shepard).
4. Burns—Story of Great Inventions (Harper and Bros.).
5. Collins—Bird's Eye View of Invention (Crowell).
6. Darrow—Masters of Science and Invention (Harcourt, Brace).
7. Doubleday—Stories of Inventors (Doubleday, Doran).
8. Forman—Stories of Useful Inventions (Century).
9. Gibson—Great Inventions and How They Were Invented (Lippincott).
10. Gibson—Heroes of Science (Lippincott).
11. Gibson—Romance of Great Inventions (Lippincott).
12. Gibson—Romance of Scientific Discovery (Lippincott).
13. Jones—Thomas A. Edison (Crowell).
14. McFee—Stories of American Invention (Crowell).
15. Meadowcroft—Boy's Life of Edison (Harper and Bros.).
16. Mowry—American Inventors and Inventions (Silver, Burdett).
17. Parkman—Conquests of Invention (Century).
18. Randell—Michael Faraday (Small, Maynard).
19. Towle—Heroes and Martyrs of Invention (Lothrop, Lee & Shepard).
20. Wright—Children's Stories of Great Scientists (Charles Scribner's Sons).

BOOKS ON RADIO

1. Ballantine—Radio Telephony for Amateurs (David McKay).
2. Cockaday—Radio Telephony for Everyone (Stokes).
3. Collins—Book of Wireless Telegraph and Telephone (Appleton).
4. Collins—Radio Amateur's Handbook (Crowell).
5. Collins—The Wireless Man, His Work and Adventures (Century).
6. Dashiell—Popular Guide to Radio (W. M. Wilkins Co.).
7. Dunlap—Radio Manual (Houghton).

8. Edelman—Experimental Wireless Stations (Wireless Press).
9. Gernsback—Radio for All (Lippincott).
10. Gibson and Others—Wireless of Today (Lippincott).
11. Goldsmith—Radio Telephony (Wireless Press).
12. Henley—222 Radio Circuit Designs (Henley).
13. Hogan—The Outlines of Radio (Little, Brown).
14. Lauer and Brown—Radio Engineering Principles (Wireless Press).
15. Lescarbau—Radio for Everybody (Scientific American).
16. Lewis—A B C of Vacuum Tubes (Henley).
17. Lodge—Talks About Radio (Doubleday, Doran).
18. Low—Wireless Possibilities (E. P. Dutton & Co.).
19. Martin—Wireless Transmission of Photographs (Wireless Press).
20. Mills—Letters from a Radio Engineer to His Son (Harcourt, Brace).
21. Morgan—Wireless Telegraphy and Telephony (Henley).
22. Pupin and Others—Radio Phone Receiving (Van Nostrand).
23. Ranger—Radio Pathfinder (Doubleday, Doran).
24. Rothafel and Yates—Broadcasting, Its New Day (Century).
25. Sleeper—Construction of Radio Sets for Beginners (Henley).
26. Smith—Modern Radio Operation (Wireless Press).
27. Snodgrass and Camp—Radio Receiving for Beginners (Macmillan).
28. Stone—Elements of Radio Telegraphy (Van Nostrand).
29. Towers—From Beacon Fires to Radio (Harper and Bros.).
30. U. S. Bureau of Standards—Principles Underlying Radio (World Radio Co.).
31. Verrill—Harper's Wireless Book (Harper and Bros.).
32. Verrill—Home Radio Up-to-Date (Harper and Bros.).
33. White—Practical Amateur Wireless Stations (Wireless Press).
34. Williams—Practical Radio (Funk & Wagnalls).
35. Yates and Pacent—Complete Radio Book (Century).

HOW TO ORGANIZE AND CONDUCT A SCIENCE CLUB

Science teachers everywhere now realize the great educational value of a club. The habits of thinking and of action that seem so hard of attainment through curricular activity come naturally and quickly through self-imposed tasks and independently planned projects.

The work of the club is always reflected in the work of the class. A science club member is an interested and interesting pupil. The work of the class stimulates activities which find an outlet in the club, and the club provides experiences on which the class can draw for building up the concepts and generalizations which are important aims in science teaching.

The time spent by the teacher in club activity can eventually be reduced to a minimum. In any event, the investment brings ample returns to the teacher.

THE CONSTITUTION

The club, when organizing, adopts a constitution. This must be brief, simple and both written and adopted by the pupils. To do this, present the following questions to the group when you meet them for the first time:

1. What shall be the aim and purpose of the club?
2. What shall be its name?
3. Who can become a member? Etc.

When all the necessary questions have been formulated, a committee is appointed to submit, a week later, a set of answers to these questions. Their report is then discussed, altered, amended and finally adopted by a majority vote. It is then typewritten and pasted into the secretary's book. The whole procedure creates a very necessary "atmosphere" for the success of the club. Below is a typical constitution for a Science Club which has been very successful.

Article I. Our aim in organizing this club is to increase our knowledge of science and to learn to experiment and to construct.

Article II. The name of the club shall be the Faraday Science Club, named after Michael Faraday, a great scientist and experimenter.

Article III. Membership.

Sec. 1. Only boys of the 7th, 8th and 9th grades can join the club.

Sec. 2. In order to join, a boy must first apply to the secretary and then appear on the programme at least once. If he can score twenty-five points in four meetings he becomes a full-fledged member.

Sec. 3. All members must score at least ten points a month in order to maintain their membership.

Article IV. Meetings.

Sec. 1. Meetings shall be held on each Friday of the school year, at 3:15 P. M., and in Room 413, if possible.

Sec. 2. Special meetings may be called by the president at any time.

Article V. Money.

Sec. 1. The weekly dues shall be five cents.

Sec. 2. The money shall be used for apparatus, books, or any other club needs.

Sec. 3. Expenditures of over one dollar must be voted by two-thirds of the members present at any meeting.

Sec. 4. Taxes not exceeding twenty cents a year may be levied, if so voted by two-thirds of the enrolled membership.

Article VI. Expulsions.

Sec. 1. A member who fails to score ten points during any month is automatically suspended.

Sec. 2. A suspended member can reinstate himself by making up his deficiency during the following month.

Sec. 3. A member suspended for more than one month is automatically expelled from the club.

Sec. 4. Members may be suspended and expelled for non-payment of dues, and for continued absence.

Article VII. Programmes.

Sec. 1. The business programme of regular meetings shall never last longer than twenty minutes.

Sec. 2. The science programme shall never last longer than one hour.

Sec. 3. The science programmes may take the following forms: Lectures, Demonstrations, School Assemblies, Exhibits, Laboratory Work and Excursions.

Sec. 4. Mr. Brown and the president, on the vote of the club, shall decide the nature of any week's programme.

Sec. 5. Any member wishing to appear on a club programme shall drop his application into the programme box at least two days in advance of the meeting.

Sec. 6. Mr. Brown and the president shall arrange the programmes.

Article VIII. Officers.

Sec. 1. The officers of the club shall be the following: President, Vice-President, Secretary, Treasurer, Sergeant-at-Arms, Librarian and Scout.

Sec. 2. Their duties shall be those usually devolving upon such officers and, in addition, the following: The Vice-President shall act as recorder of the science programmes. The Scouts shall investigate places where excursions for the club may be arranged. The Sergeant-at-Arms is custodian of apparatus and acts as assistant to lecturers and demonstrators.

Sec. 3. Elections shall be held at the beginning of each school year.

Sec. 4. Officers may resign and may be impeached.

Sec. 5. A three-quarters vote shall be needed for impeachment.

Sec. 6. Applications must be submitted to the club in written form.

Sec. 7. Elections may be held whenever an office is declared vacant.

Article IX. This constitution may be amended by a three-quarters vote.

WHAT TYPE OF CLUB WILL YOURS BE?

The successful club provides a programme of diverse interests and activities. These must be adapted to the needs of the particular group and suited to the varied abilities within the group.

Occasionally we find a successful science club which specializes in one branch of science and limits all its activities to that branch. It has been our experience, however, that such a club has an exceptional reason for existence. Where a director is available who is specially talented along one line, or where a single interest brings together a small group of members, it is possible to carry on as a Camera Club, a Bird Club or a Radio Club. Clubs of this type are found most often in the Senior High School.

The great majority of science teachers interested in Science Clubs have neither the specialized equipment nor technic to develop a vital and continuous programme in one narrow field of science. To most pupils, too, the appeal is along general science rather than specific science lines. It is

among pupils of the Elementary and Junior High Schools where the diversified programme of activities which we describe below takes greatest hold.

THE DEMONSTRATION PROGRAMME

One of the most popular types of programmes is one in which individual members are given opportunity to present experiments to the club. The difficulty here is to get every member to share in the programme. Unless something is done by the director to furnish ideas and often materials, the club may run short of demonstrators and demonstrations.

As a solution to this difficulty we offer the Requirement Plan. Just as the club adopts a constitution, so it must adopt a set of requirements or accomplishments. The latter, as will be seen in the list below, represents goals and objectives which each member is striving to reach. Each objective is given a different numerical weight, and each member seeks to attain a certain point score by the end of the semester.

To be awarded the points which any requirement carries, a member must prove his worth by performing that activity at a meeting. These performances make up the Demonstration Programme.

When the Requirement Plan has been adopted, each member should be provided with a copy. To claim points, a member states his claim on a slip of paper which he deposits in a box provided for that purpose. The day before the club meets, the president removes all the slips and brings them to the director. Each claim is virtually a number on the programme. The programme is then arranged in the best possible order and the necessary equipment is made ready. It is understood that all special apparatus will be supplied by the demonstrators themselves. The programme consists of calling on the members in the order arranged, with questions and discussion following each number.

A TYPICAL REQUIREMENT PLAN

	POINTS
1. For constructing a piece of apparatus	10
2. For demonstrating an experiment	10
3. For performing and explaining a chemical experiment	10
4. For devising any new experiment	15
5. For making a discovery or invention (so recognized by the club),	25 to 50
6. For proposing an original idea in science	1
7. For working out that idea, or any one else's idea, in practice	5 to 50
8. For rendering a report or lecture to the club on some important article in any of the magazines or newspapers	5
9. For keeping a well-organized Science Scrap Book	10 to 25
10. For being able to calculate the water, gas and electricity bills	5
11. For being able to regulate a clock	2
12. For being able to do simple wiring of bells and batteries	5
13. For being able to wire up a desk lamp	3
14. For being able to replace a burnt-out electric socket	5
15. For being able to repair a small electric motor	5

16. For being able to operate a lantern-slide machine 5
17. For being able to do minor repairs on a bicycle, skates, window-shades, etc. ..... 5 to 10
18. For being able to take good pictures ..... 5 to 15
19. For being able to print pictures 10
20. For being able to develop pictures 20
21. For being able to measure a person's blood pressure 5
22. For being able to measure humidity 5
23. For delivering a lecture before the club 5
24. For making a trip to some industrial plant and reporting to the club, 5 to 15
25. For reading a book on science and reporting to the club ..... 10 to 20
26. For being able to explain ten of the things, mechanisms or processes listed on the club list 10
27. For being able to explain ten of the phenomena listed on the club list 10
28. For knowing the names of twenty great scientists 5
29. For knowing what great thing each is remembered for 5
30. For being able to give some important facts about the lives of ten of them 5
31. For being able to use a telescope 5
32. For being able to identify five important constellations 5
33. For being able to identify ten different trees 10
34. For a good collection of tree leaves 10
35. For being able to identify ten flowers 10
36. For a good collection of pressed flowers 10
37. For being able to identify ten birds 10
38. For being able to identify ten insects 10
39. For a good collection of insects 10
40. For being able to identify ten stones or minerals 10
41. For a good collection of stones or minerals 10
42. For being able to use a microscope 5
43. For being able to grow micro-organisms 10
44. For being able to demonstrate simple first-aid methods 10
45. For being able to hook up a radio set 5
46. For being an officer, scout or librarian of the science club 5
47. For helping in the science laboratory 5
48. For helping some boy to work out his project 5
49. For excellence in laboratory work 5
50. For excellence in class work 5

The above list is merely by way of suggestion. Each club should select those activities which make the greatest appeal to its members, and the relative weights should be adjusted by the club and the director.

In order to stimulate members in the scoring of points, the club can offer a series of prizes. These should be awarded to every member who reaches a definite level, such as 150 points, 200 points, 300 points, etc. In fact, different prizes for each of the maximum point levels may be set. It is wise to let the competition be between each member and himself, rather than between one member and another.

In the beginning, it is advisable for the director to assume the responsibility of deciding on the claims for points. After standards of excellence have been established, this responsibility may well be delegated to the club as a whole.

The progress of each member in his acquisition of points may be charted and exhibited conveniently by using the form below.

In many of the clubs with which we have had experience, arm-bands were ordered for each member. These bands, made of cheap felt, in school colors, and carrying the letters F. S. C. (Faraday Science Club) were worn by club members when the club held its sessions.

THE_____SCIENCE CLUB

	ACTIVITIES	MEMBERS	List in these spaces the NAMES OF THE MEMBERS →						
1	List in these	5							
2	spaces the different		10		15				
3	items in			25				5	
4	the			5		3			
5	Point system		10				5		
	(One on a line)								
	POINT TOTALS								

SCIENCE CLUB CHART

HOW THE SCIENCE CLUB INITIATES ITS NEW MEMBERS

PRES.: The next order of business is to initiate John Sellers into membership of our club. All members will please rise as John steps up to the front and takes the Initiate Seat, facing the club. (John steps up and then sits down. His chair is decorated with the club banner. The room is darkened and the light from a projection lantern is cast on him and the chair.

PRES. John, you have applied for membership in our club, the members have investigated your record and are glad to elect you to our club. But, before you are finally admitted, you must answer certain questions and you must show your ability to perform certain tasks. Are you willing and ready?

JOHN: Yes, sir.

PRES.: First, why do you wish to become a member of our science club?

JOHN: I want to join this club, because I am interested in science, because I want to learn more about the way scientists work and because I think the members of this club spend their extra time in a very pleasant way.

PRES.: The secretary will please take down his answers. John, what have you done in science which entitles you to become a member of our club?

JOHN: I have a good class record in science. I have a good deal of sci-

entific apparatus which I have made myself. I have done small repairs on our automobile and our vacuum cleaner. I do all the wiring of electric lamps and bells at home. I have built my own radio set and I have an idea for an invention.

PRES.: Tell us your idea for an invention.

JOHN: If it is compulsory for me to tell, I will; but I would prefer to wait till I've worked it out.

FRED.: Mr. President, I move that John be permitted to tell us about his invention whenever he is ready. There have been many scientists in the past whose ideas have been laughed at. I don't think we ought to discourage him.

PRES.: If there are no objections, we will waive the answer to my last question. John, name five great men of science.

JOHN: Newton, Pasteur, Faraday, Lavoissier and Edison.

PRES.: Who discovered Oxygen?

JOHN: Priestly.

PRES.: Name five important acids.

JOHN: Hydrochloric, nitric, sulphuric, tartaric and acetic.

PRES.: Name the lightest metal.

JOHN: Sodium.

PRES.: Who was Ohm?

JOHN: Ohm was a German scientist, after whom the electrical unit of resistance was named.

PRES.: On the apparatus table is a magnetized rod, with poles unnamed and another with north and south poles marked. Mark the correct poles on the rod which is unmarked.

(*John tests the two magnets to find which ends attract and which ends repel. Gives his answer.*)

PRES.: Bend this tube into an L.

(*John lights a burner, first attaching a fish-tail spreader, and does as he is told. The president continues with several other laboratory tasks.*)

PRES.: You have answered all our questions and you have performed your tasks very well. I have the honor to proclaim you a full-fledged member of our club. Here is our club insignia which you must wear to school on each meeting day and here is a copy of our constitution which you must read carefully and save for reference. Before a month is over you will be called to appear on one of our programmes.

(*Applause.*)

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